farmers. The large soil particles are ground up into finer ones by the gizzard (a grinding organ of their alimentary canal). Thus, it provides more surface to the soil for water absorption.

Worm castings of the earthworms are of manurial value. The nitrogenous wastes, and other secretions of this worm also form important plant food. In this way they increase the fertility of the soil. The process of increasing fertility of soil by earthworm is called **vermicomposting**. Earthworms reduce both acidity and alkalinity of the soil and, thus, create optimum conditions for plant growth. Earthworms are also used as food in some countries such as China, Japan, Myanmar (Burma), Australia, etc. They are used as bait for catching the fishes all over the world. Many tribal communities in India use earthworm in the form of medicine to cure bladder stones, jaundice, piles, diarrhoea, etc. Earthworm may cause some harm to man. They may damage young and tender palnts. During rainy season, they cause soil erosion by making burrows to some extent. They spoil the play-grounds by digging burrows in them. Sometimes, their burrows cause the loss of water from the irrigated lands. Some earthworms serve intermediate hosts for some parasites such as tapeworm of chicken and lung nematode of pigs.

The population of earthworms is declining due to excess use of pesticides and chemical fertilizers. Since many animals such as frogs, lizards and birds eat earthworm, hence these animals are also being affected indirectly and resulting in ecological imbalance.

PERIPLANETA (Cockroach)

The cockroaches are one of the most common insects, usually found in the houses. Two kinds of cockroaches are usually found in India, *viz.*, *Periplaneta americana* and *Blatta orientalis*, which can be distinguished as follows :

Differences between Periplaneta americana and Blatta orientalis

Periplaneta americana	*Blatta oreintalis*
1. It is about 5 cm. long and reddish brown in colour.	1. It is about 2-5 cm. long and dark brown in colour.
2. Both male and female have large, well developed wings, covering the entire abdomen.	2. The wings of the male are shorter than the body, while in the female the wings are rudimentary.
3. It is a native of America and has spread to the other parts of the world.	3. It is a native of Asia but has spread to other parts of the world also.

Systematic position

Phylum	—	Arthropoda
Class	—	Insecta
Order	—	Dictyoptera
Family	—	Blattidae
Genus	—	*Periplaneta*
Species	—	*americana*
Common Name	—	Cockroach

Habitat. Cockroaches are found in warm, dark and damp places. They commonly inhabit kitchens, restaurants, store houses, godowns, railway wagons, ships, etc. They are numerous in underground drains.

Habits. They are **nocturnal** insects prefering darkness and become active during night, but remain hidden under some objects and take rest during day time. Cockroaches are **omnivorous** in diet, feeding on almost all kinds of food matter including human food, paper, leather, cloth and

even dead bodies of their fellows (show **cannabilism**). They prefer starch containing food. Cockroaches are **cursorial** insects, *viz.*, run very fast. They fly very rarely as they are not good fliers.

Cockroaches are unisexual, *viz.*, male and female sexes are found in different individuals. They show **sexual dimorphism**, *viz.*, one sex can be distinguished from the other externally. Cockroaches are **oviparous**, *viz.*, they lay eggs. Parental care is seen in these insects. The young cockroaches, called the **nymphs**, resemble the adults in most of the characters, but are smaller in size, pale in colour, devoid of wings. Nymphs undergo **moulting** or **ecdysis**, in which the casting of older skin takes place. The nymphs gradually change into adults.

Lizards, birds, moles and even toads are the chief enemies of the cockroaches.

Morphology or External Characters

Shape, Size and Colour. The body is dorsoventrally flattened, elongated and bilaterally symmetrical. The adult cockroach is about 2 to 4 cm. in length and about 1 cm. in width. The colour is shining reddish brown.

Exoskeleton. The body of cockroach is externally covered by hard brown chitinous plates, the **sclerites**, which constitute the exoskeleton. The sclerites are joined with one another by thin flexible, soft **articular** or **arthrodial membranes**.

Body Divisions. The body of cockroach is distinctly divided into three regions, *viz.*, head, thorax and abdomen. A very small neck is also present in between the head and thorax.

I. Head

It is the anterior most region of the body, which lies at right angle to the long axis. It is formed by the fusion of six segments. The proximal semi-circular broader end of the head is directed upwards, while the distal narrow, mouth bearing end is directed downwards. This type of head is called **hypognathus**. The neck allows the movement of the head in all possible directions. Head is covered by sclerites and bears sense organs, mouth parts and mouth.

1. **Sclerites**. In adult all sclerites of the head are fused to form a **head capsule**. The top of

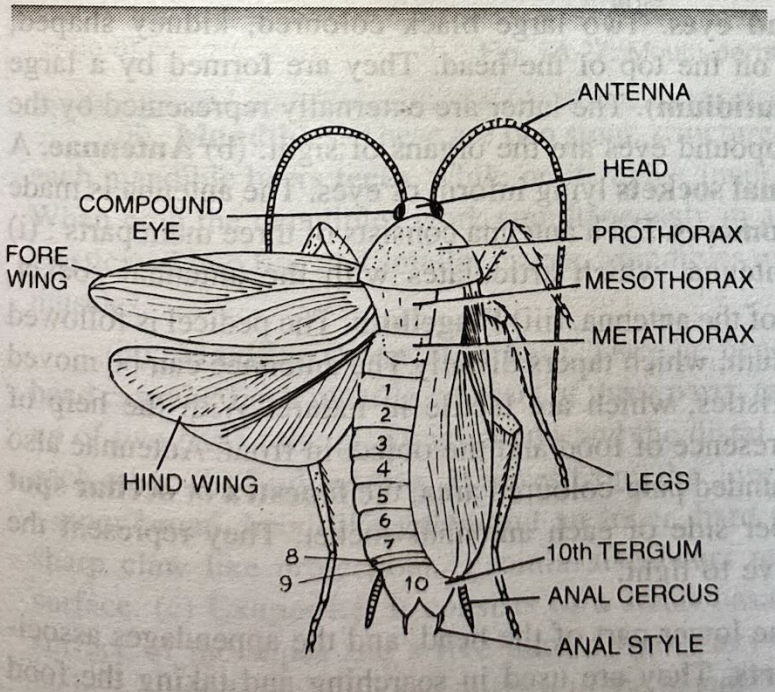


Fig. 7A.23. Male cockroach in dorsal view.

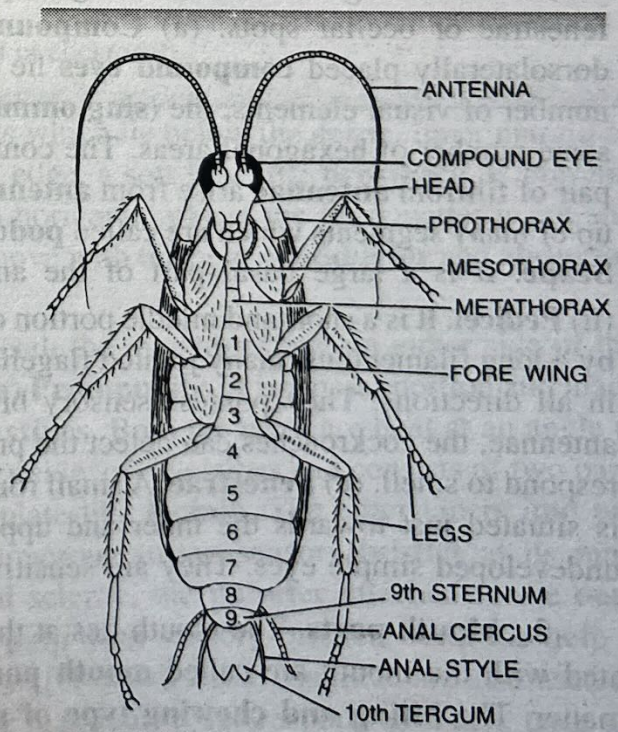


Fig. 7A.24. Male cockroach in ventral view.

the head capsule is known as **vertex**. The latter is divided by 'λ' shaped **epicranial suture** into two **epicranial plates**. A triangular plate, the **frons** is found in front of the epicranial plates. The frons is followed by a rectangular plate, the **clypeus**. A **frontoclypeal suture** is present in between the frons and clypeus. A movable chitinous flap, the **labrum** hangs from the lower edge of the clypeus. A **labroclypeal suture** is found in between the clypeus and labrum. Two cheek sclerites, the **genae**, lie vertically just below the eyes at the lateral side.

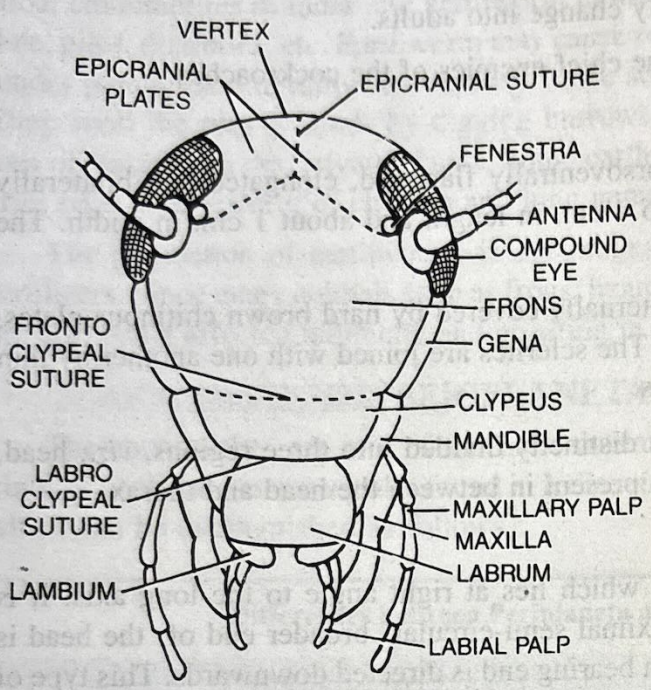


Fig. 7A.25. Head of cockroach in front view.

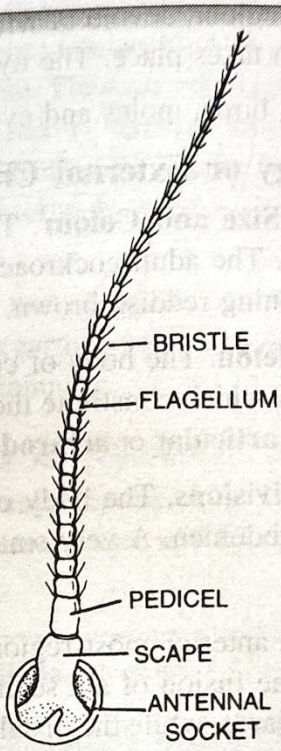


Fig. 7A.26. Antenna of cockroach.

2. **Sense organs**. The sense organs present on the head are compound eyes, antennae and fenestrae or ocellar spots. (a) **Compound eyes**. Two large black coloured, kidney shaped, dorsolaterally placed **compound eyes** lie on the top of the head. They are formed by a large number of visual elements, the (**sing ommatidium**). The latter are externally represented by the same number of hexagonal areas. The compound eyes are the organs of sight. (b) **Antennae**. A pair of filifrom **antennae** arise from **antennal sockets** lying infornt of eyes. The antenna is made up of many segments which are called **podomeres**. Each antenna consists of three main parts : (i) **Scape**. It is a large basal part of the antenna, which articulates with the antennal socket. (ii) **Pedicel**. It is a short and middle portion of the antenna. (iii) **Flagellum**. The pedicel is followed by a long filamentous, many jointed flagellum, which tapers distally.The antennae can be moved in all directions. They possess sensory bristles, which are tactile in nature. With the help of antennae, the cockroaches can detect the presence of food and the object in front. Antennae also respond to smell. (c) **Fenestrae**. A small rounded pale-coloured area, the **fenestra** or **ocellar spot** is situated just towards the inner and upper side of each antennal socket. They represent the undeveloped simple eyes. They are sensitive to light.

3. **Mouth parts**. The mouth lies at the lower part of the head, and the appendages associated with the mouth are called **mouth parts**. They are used in searching and taking the food matter. The **biting and chewing type of mouth parts** of cockroach consist of a *labrum*, two *mandibles*, two *maxillae, a labium* and a *hypopharynx*.

(i) **Labrum**. It is a broad, chitinous flap, which hangs from the distal end of the clypeus. It is also called as upper lip. A thin plate, the **epipharynx**, is fused to the inner surface of the labrum. The epipharynx bears the organs of taste. The labrum holds the food particles during the feeding.

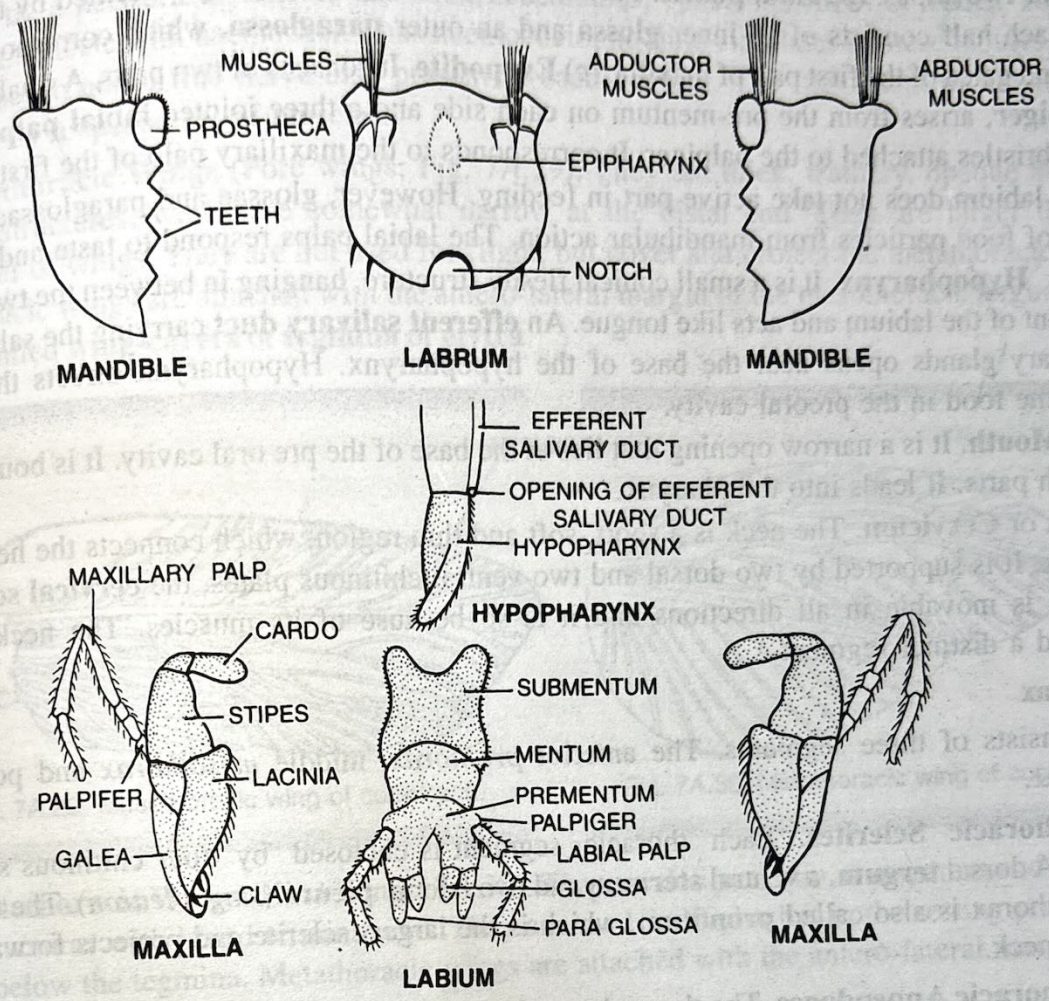


Fig. 7A.27. Mouth parts of cockroach.

(ii) **Mandibles**. These are two stout, structures which lie below the genae. Inner margin of each mandible bears **teeth**, while on its upper inner edge, a soft lobe, the **prostheca**, is present. When both the mandibles work simultaneously in a horizontal plane, the food matter is cut and masticated into fine and smaller pieces. Mandibles move with the help of **adductor** and **abductor** muscles.

(iii) **Maxillae (First Maxillae)**. They lie beneath the mandibles one on either side of the head capsule. Each maxilla consists of three parts. (a) **Protopodite**. It is a basal portion and made up of two parts : the proximal **cardo** and the distal **stipes**. Both the parts are bent at an angle to each other. (b) **Endopodite**. It arises from the inner side of the stipes and consists of two parts : outer broad, hood-like **galea** and an inner, hard plate-like **lacinia**. The latter tapers into two sharp claw like projections. Lacinia also bears numerous strong sensory bristles at its inner surface. (c) **Exopodite**. It consists of a small basal sclerite, the **palpifer** attached to the outer surface of the stipes and a five jointed **maxillary palp** with sensory bristles. With the help of lacinia, it holds the food and gives it to the mandibles for mastication. Maxillae are also used for cleaning the antennae and the first pair of legs. The maxillary palps respond to touch, taste and smell.

(iv) **Labium (Second Maxillae)**. It is a single structure which represents the fused second pair of maxillae, lying behind the mouth and forming a sort of lower lip. It comprises the following parts. (a) **Protopodite**. It consists of a proximal large part, the **sub-mentum**, the middle small **mentum** and the distal **pre-mentum**. The sub-mentum and mentum are together called as **post-mentum,** which probably represents the fused cardos, while pre-mentum is perhaps the fused portion of two stipes. (b) **Endopodite**. Partially fused endopodites are represented by the **ligula** whose each half consists of an inner **glossa** and an outer **paraglossa**, which correspond to the lacinia and galea of the first pair of maxilla. (c) **Exopodite**. It consists of two parts. A small sclerite, the **palpiger**, arises from the pre-mentum on each side and a three jointed **labial palp**, bearing sensory bristles attached to the palpiger. It corresponds to the maxillary palp of the first maxilla.

The labium does not take active part in feeding. However, glossae and paraglossae prevent the loss of food particles from mandibular action. The labial palps respond to taste and smell.

(v) **Hypopharynx**. It is a small conical fleshy structure, hanging in between the two maxillae in front of the labium and acts like tongue. An **efferent salivary duct** carrying the saliva from the salivary glands opens near the base of the hypopharynx. Hypopharynx directs the saliva towards the food in the preoral cavity.

4. **Mouth**. It is a narrow opening that lies at the base of the pre oral cavity. It is bounded by the mouth parts. It leads into the pharynx.

Neck or **Cervicum**. The neck is a short, soft and thin region, which connects the head with the thorax. It is supported by two dorsal and two ventral chitinous plates, the **cervical sclerites**. The neck is movable in all directions and it is so because of its muscles. The neck is not considered a distinct segment.

II. Thorax

It consists of three segments. The anterior *prothorax*, middle *mesothorax* and posterior *metathorax*.

(i) **Thoracic Sclerites**. Each thoracic segment is enclosed by four chitinous skeletal sclerites. A dorsal **tergum**, a ventral **sternum** and two lateral **pleura** (*sing. pleuron*). The tergum of the prothorax is also called **pronotum**, which is the largest sclerite and projects forwards to cover the neck.

(ii) **Thoracic Appendages**. The thorax bears three pairs of legs and two pairs of wings.

(a) **Legs**. Each thoracic leg segment bears a pair of walking legs. According to their position, they are named as **pro-legs**, **meso-legs** and **meta-legs**. They arise in between the sterna and pleura. All the three pairs of jointed legs are similar in structure. Each leg is composed of five **podomeres**. **Coxa**. It is a small, hard podomere, which articulates with the thoracic segment in between the pleuron and the sternum. **Trochanter**. It is a small, hard podomere which lies next to the coxa. Trochanter articulates movably with the coxa, but is fused with the next podomere, the femur. **Femur**. It is a long and the stoutest part of the leg, bearing sensory bristles. **Tibia**. It is a thin, slender and the longest part of the leg, which also possesses bristles. **Tarsus**. It is a terminal part of the leg and composed of five **tarsomeres**. The terminal tarsomere is known as **pretarsus**, which bears two sharp curved **claws** and a soft hairy pad, the **pulvillus**, in between the two claws. Each tarsomere possesses a soft adhesive

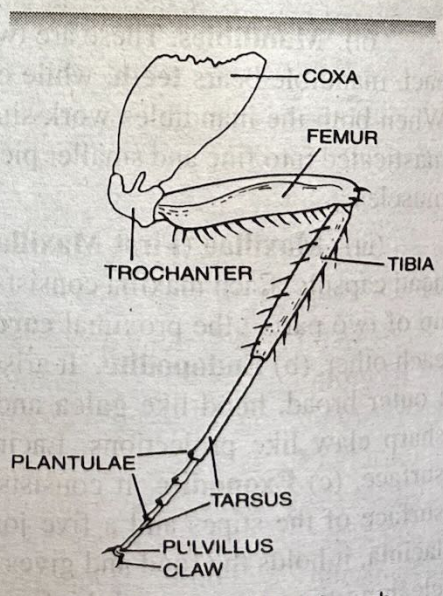


Fig. 7A.28. Leg of cockroach.

pad, the **plantula** on its lower side. The claws and pads help the cockroach in grasping the substratum firmly.

(b) **Wings**. Two pairs of wings are found in cockroach. The first pair is mesothoracic and attached with the tergum of the mesothorax. The second pair is metathoracic connected with tergum of metathorax. In fact, the wings are the membranous outgrowths of the body wall, supported by a network of slender and branched tubules, called **nervures** or **veins**. These tubules communicate with haemocoel. Thus haemocoelomic fluid circulates in these tubules. An air tube or trachea and a fine nerve also present in each nervure. The movement of the wings is controlled by a special set of muscles.

Mesothoracic Wings (Fore wings; Fig. 7A.29). They are thick, leathery, opaque and dark coloured structures, which are somewhat narrow at the distal end. They are larger than the second pair of wings. They are not used for flight, but cover and protect the metathoracic wings. Mesothoracic wings are attached with the antero-lateral margin of the mesothoracic tergum. They are also called **wing-covers** or **tegmina** or **elytra**.

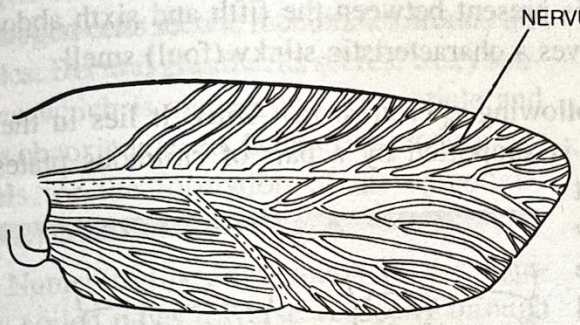


Fig. 7A.29. Mesothoracic wing of cockroach.

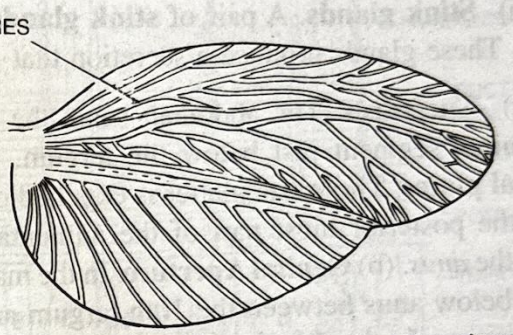


Fig. 7A.30. Metathoracic wing of cockroach.

Metathoracic Wings (Hind Wings; 7A.30). They are delicate, thin, transparent and membranous structures with broad terminal end. They are used for flight, but in the resting position, lie folded below the tegmina. Metathoracic wings are attached with the antero-lateral margin of the metathoracic tergum.

(iii) **Thoracic Spiracles**. There are present two pairs of thoracic spiracles. The first pair of *spiracles* is known as mesothoracic, lying in front of the mesothorax between the bases of first and second pairs of legs. These are the largest spiracles. The second pair of spiracles is called metathoracic, lying in front of the metathorax, between the bases of second and third pairs of legs. Spiracles are meant for intake of fresh air and release of foul air.

III. Abdomen

It is the largest part of the body narrows posteriorly. The abdomen in both male and female consists of ten segments.

(i) **Abdominal Sclerites**. A typical abdominal segment is enclosed by four sclerites. A dorsal **tergum**, one ventral **sternum** and two lateral **pleura** are found in a typical thoracic segment. There are present ten terga. The seventh tergum covers the eighth tergum in male and eighth and ninth terga in the female cockroach. The tenth tergum is large and notched in the middle and projects backwards beyond the body. The abdomen bears nine sterna, while the tenth one is absent. In male all the nine sterna are seen, but in female cockroach only seven sterna are visible, the seventh one conceals the eighth and ninth sterna. The abdomen in both male and female cockroaches consists of 10 segments. In females, the 7th sternum is boat shaped and together with the 8th and 9th sterna forms a **gential pouch** (brood pouch) which is divisible into a **genital**

chamber infront and vestibulum (oothecal chamber) behind. Genital chamber contains female gential pore, spermathecal pores and collaterial glands. In males, genital pouch lies at the hind end of abdomen. It contains dorsal anus ventral male gential pore and gonapophyses (phallomeras). The abdomen of female cookroach is broader than the male.

(ii) **Abdominal Appendages**. The posterior end of the abdomen bears the following appendages : (a) **Anal cerci**. These are paired, jointed outgrowths, which arise from the 10th tergum. The anal cerci are long and thick structures found in both male and female cockroach and are sensitive to touch. They are also sensitive to sound and other vibrations. (b) **Anal styles**. These are also paired but thin, small unjointed outgrowths, which project backwardly from the sides of the 9th sternum of the male cockroach only. They are also sensitive to touch. (c) **Gonapophyses**. In both the sexes the genital aperture is surrounded by some sclerites, known as *gonapophyses*. In male, they arise from the 9th segment and form the **external genitalia** or **external genital organs** to help the insect in copulation. In the female, gonapophyses belong to the 8th and 9th abdominal segments to form an **ovipositor**. The latter is used to guide the fertilized eggs towards the oothecal chamber for ootheca formation.

(iii) **Stink glands**. A pair of **stink glands** is present between the fifth and sixth abdominal terga. These glands produce a secretion that gives a characteristic stinky (foul) smell.

(iv) **Apertures**. The abdomen bears the following apertures: (a) **Anus**. It lies in the 10th abdominal segment just below the tergum. It is supported by a pair of chitinous plates, the **podical plates**. The waste matter is expelled out from the posterior most part of the alimentary canal, the *anus*. (b) **Genital Aperture**. In the male it lies below anus between the 10th tergum and 9th sternum. In the female, it is situated in the 8th sternum. Female genital aperture opens into the genital chamber. In both the sexes genital aperture is surrounded by gonapophyses. (c) **Abdominal Spiracles**. There are present eight pairs of abdominal spiracles. The first pair of abdominal spiracles is dorsal in position and lies on the lateral margins of the first abdominal tergum. The remaining abdodminal spiracles are situated on the sides of their corresponding segments on the pleura between the terga and sterna. The wall of the spiracles is provided with fine bristles to check the entry of dust particles while oxygen enters the respiratory tubes, the **tracheae**, for respiration.

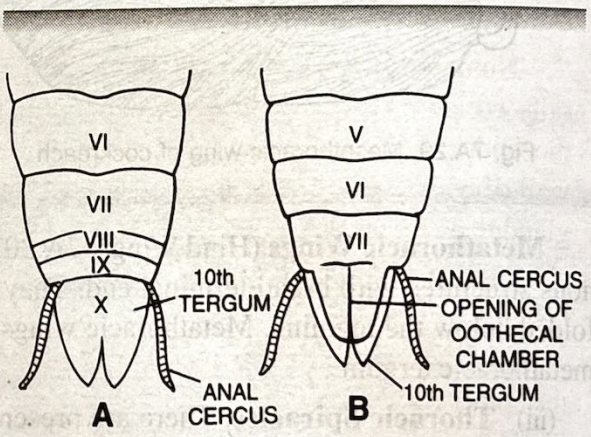


Fig. 7A. 31. Posterior end of female cockroach. A, dorsal view. B, ventral view.

Differences between Female and Male Cockroach

Female Cockroach	*Male Cockroach*
1. The abdomen is short and broad.	1. The abdomen is long and narrow.
2. Anal styles are absent.	2. A pair of unsegmented anal styles is present.
3. Brood pouch is present.	3. Brood pouch is absent.
4. The 8th and 9th terga are covered by the 7th tergum and are not very distinct.	4. The 8th tergum is covered by the 7th tergum and thus not very distinct.
5. Females have shorter antennae.	5. Males have larger antennae.

Anatomy

Body Wall (Fig. 7A.32)

Body wall of cockroach consists of the following three layers.

(i) **Cuticle**. It forms the outermost layer of the body wall secreted by the epidermis. It is made up of chitin which becomes hard to form the exoskeleton. The cuticle consists of three sub-layers. (a) **Epicuticle**. It is outer, thin and waxy layer which is usually impermeable to water. Chitin is absent in epicuticle. (b) **Exocuticle**. It is the middle laminated, tough, chitinous pigmented thinner layer. (c) **Endocuticle.** It is a thick innermost layer formed of soft laminated chitin.

The cuticle forms some immovable **spines** which are tactile in function.

(ii) **Epidermis** (= **Hypodermis**). It lies below the cuticle and consists of single layered columnar cells. It secretes the cuticle. Certain cells of the epidermis are modified into **trichogen cells** which secrete movable bristles. **Tormogen cells** secrete membranes around the bristles. **Dermal gland** cells secrete waxy substance which is spread over the cuticle and gives obnoxious smell. **Oenocytes** produce materials for the formation of the epicuticle. Oenocytes also influence moulting (**ecdysis**).

Numerous fine **pore canals** which are spirally coiled tubes traverse vertically through the endocuticle and exocuticle of the body wall of cockroach. These are the ducts of the glandular cells of underlying epidermis. They are supposed to influence flexibility and permeability of cuticle.

(iii) **Basement membrane**. It lies beneath the epidermis. It is composed of flattened cells.

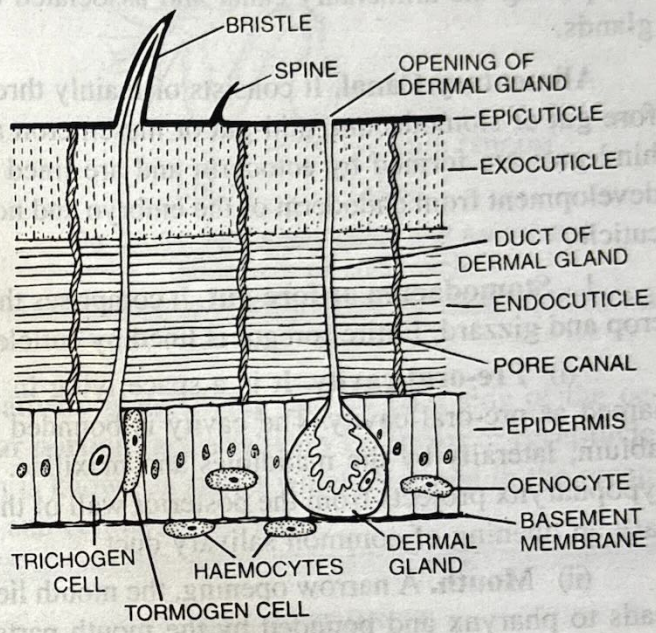


Fig. 7A.32. T.S. Body wall of Cockroach.

Endoskeleton

At some places, certain processes (projections) of exoskeleton extend into the body and form **endoskeletal elements**. These provide attachment to the muscles and hence called **apodemes**. (i) A tent-like plate called **tentorium**, forms the endoskeleton of head. (ii) In the thorax, separate processes of sternites of the three segments form endoskeleton. (iii) Abdomen of cockroach does not have endoskeletal elements.

Body Cavity

True coelom is found during embryonic development. In adults, original coelom is present around the gonads. The body cavity is filled with blood and, therefore, called **haemocoel**. The haemocoel is divided by two horizontal perforated partitions or **diaphragms** into three spaces, the **pericardial, perivisceral** and **perineural sinuses**. (Fig 7A.37)

Fat Body (= Corpora Adiposa)

Fat body fills most of the perivisceral sinus around the gut. Fat body consists of numerous solid lobules. It is bound by a fine membranous covering of connective tissue. Each lobule contains several types of cells. Four cell types are of special significance. :

(i) **Trophocytes**. They contain reserve food in the form of fats, glycogen and protein. (ii) **Mycetocytes**. These cells contain symbiotic bacteria which help in synthesis of some amino acids and vitamins and of glycogen from glucose. (iii) **Oenocytes**. They are probably concerned with some intermediary metabolism at time of ecdysis. (iv) **Urate cells**. They absorb nitrogenous waste products from the haemolymph and synthesize uric acid from these for storage.

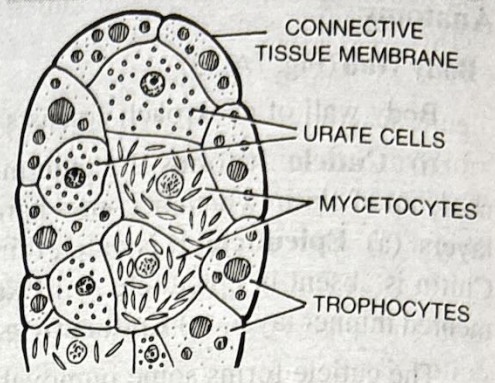


Fig. 7A.33. A lobule of fat body in section.

Digestive System

The cockroach has well developed digestive system comprising the alimentary canal and associated digestive glands.

Alimentary Canal. It consists of mainly three parts : fore-gut or stomodaeum, mid-gut or mesenteron and the hind-gut or proctodaeum. The fore and hind-guts are formed by ectoderm and are lined by the cuticle internally, while the mid-gut is development from endoderm of the embryo and not lined by the cuticle. Entire foregut is lined by cuticle.

1. **Stomodaeum or fore-gut**. It comprises the pre-oral cavity, mouth, pharynx, oesophagus, crop and gizzard. Entire foregut is lined by cuticle.

(i) **Pre-oral cavity.** It is a space lying in front of the mouth to receive the food, hence named as pre-oral cavity. The cavity is bounded anteriorly by the labrum, posteriorly by the labium, laterally by the mandibles and maxillae. Inside the cavity, a tongue like structure, the hypopharynx projects from the posterior wall of the pre-oral cavity. The hypopharynx bears at its base an opening of common salivary duct.

(ii) **Mouth.** A narrow opening, the mouth lies at the base (bottom) of pre-oral cavity which leads to pharynx and bounded by the mouth parts.

(iii) **Pharynx.** It is a short tube-like structure which lies in the head region and leads into the oesophagus.

(iv) **Oesophagus.** It is a tubular thin walled structure lying in the neck and succeeds anterior part of the thorax. It continues into the crop.

(v) **Crop.** The oesophagus dilates to form a large thin walled pear shaped crop. The crop is very large part of the alimentary canal of the cockroach where food is stored. It opens into the gizzard.

(vi) **Gizzard (= Proventriculus).** It is a thick walled some what rounded structure whose walls are muscular and greatly folded. It bears six muscular folds which are covered by chitinous conical plates, the **teeth**, used for grinding the food. Its wall consists of strong circular muscles which are needed by the gizzard for grinding.

2. **Mesenteron or mid-gut.** It is a thin walled somewhat coiled tube with almost uniform thickness. It is the only part of the alimentary canal which is not lined by the cuticle. Main digestion and absorption of food is carried out here. A **peritrophic membrane** is formed around the food in the mid gut. This membrane is permeable to digestive enzymes and digested foods. From the junction of mid-gut and gizzard arises six to eight finger-like blind structures called the **hepatic caecae** or **gastric caecae**. The junction of mid-gut and hind-gut is marked by the presence of 100–150 yellow fine thread-like structures, the **Malpighian tubules**. The tubules are excretory in function.

3. **Proctodaeum or Hind-gut.** It comprises the ileum, colon, rectum and anus. It is ectodermal in origin.

(i) **Ileum.** The mid-gut continues into the ileum. It is short and relatively narrower. Anteriorly it bears thread like Malpighian tubules. The ileum passes undigested food into the colon.

(ii) **Colon.** Actually it is a dilation of ileum and is the longest, relatively thicker and coiled part of hind gut. It leads into the rectum.

(iii) **Rectum.** It is the terminal short thick walled structure. Its internal lining is thrown to form six thick longitudinal folds known as **rectal papillae**. The latter help in the absorption of water.

(iv) **Anus.** It is a slit like opening of the alimentary canal lying at the hind end of the abdomen below the 10th tergum.

Hind gut is broader than mid gut.

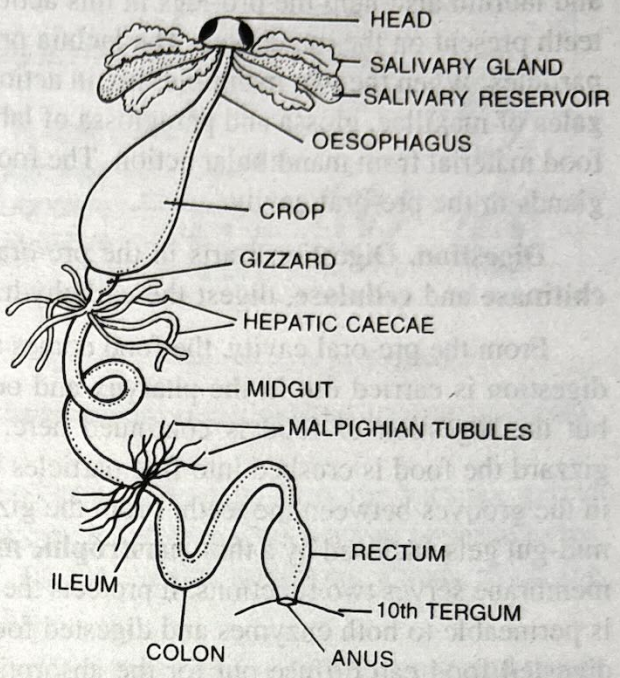


Fig. 7A.34. Alimentary canal and associated structures of cockroach.

Digestive Glands. They are as follows :

(i) **Salivary glands**. There are paired salivary glands lying one on each side of the oesophagus and crop. Each gland has two **glandular portions** and a **salivary reservior** or **receptacle**. The secretion secreted by the glandular portion is known as **saliva** which is stored in the receptacles. The saliva contains **amylase, chitinase** and **cellulase** enzymes.

(ii) **Hepatic caecae**. There are six to eight tubular structures arising from the anterior end of the mid-gut. Hepatic caecae are lined by the glandular cells which secrete digestive secretion containing amylolytic, proteolytic and lipolytic types of enzymes.

(iii) **Mid-gut lining**. The mid-gut is lined by glandular epithelial cells which secrete a digestive secretion containing proteolytic, amylolytic and lipolytic enzymes.

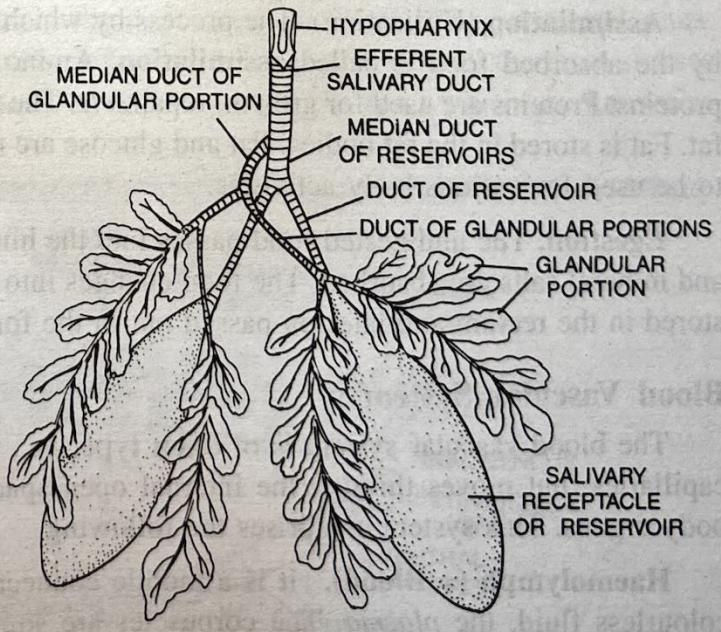


Fig. 7A. 35. Salivary glands and receptacles of cockroach.

Food. Cockroach is **omnivorous**. Its food consists of almost all types of organic matters, *i.e.,* paper, bread, cloth, vegetables, meat, etc. It also eats dead bodies of its fellows (**cannibalism**) and other insects. It is interesting to note that it even feeds upon its caste. Cockroach prefers food containing more of starch and sugar.

Ingestion. First the food is searched with the help of antennae and maxillary and labial palps

as they bear sense organs. The pro-legs pick up and bring food to the pre-oral cavity. The labium and labrum also help the pro-legs in this action. In the pre-oral cavity, the food is masticated by teeth present on the mandibles. The lacinia present in the maxillae also cut the food into smaller particles. When the two mandibles are in action, the food is held in proper position by lacinia and galea of maxillae, glossa and paraglossa of labium. The labrum and labium prevent the escape of food material from mandibular action. The food is mixed with the saliva poured from the salivary glands in the pre-oral cavity.

Digestion. Digestion starts in the pre-oral cavity. The enzymes of saliva namely **amylase**, **chitinase** and **cellulase**, digest the carbohydrates partially.

From the pre-oral cavity, the food comes to pharynx, oesophagus and then into the crop. No digestion is carried out in the pharynx and oesophagus. Though the crop is mainly for storage but the digestion of food is continued here. Thereafter, the food reaches the gizzard. In the gizzard the food is crushed into fine particles by the teeth and filtered through the bristles found in the grooves between the teeth. From the gizzard, food passes into the midgut. The food in the mid-gut gets enclosed by a thin, **peritrophic membrane** secreted by the wall of the mid-gut. This membrane serves two functions. It protects the delicate mid-gut lining from hard food particles. It is permeable to both enzymes and digested food so that the enzymes can reach the food, and the digested food can diffuse out for the absorption.

The digestive secretions secreted by the mid-gut lining and the hepatic caecae contain : (a) **Invertase**, **maltase** and **lactase** which complete the digestion of carbohydrates, (b) **Trypsin**, **proteases** and **peptidases** which digest the proteins and (c) **Lipases** which digest the fats.

Most of the digestion is carried out in the midgut.

Absorption and Transportation. Digested food is absorbed by the internal lining of the mid-gut and also by the hepatic caecae through diffusion. The absorbed food is transferred into the blood present around the alimentary canal. The food is circulated to the various parts of the body through the blood.

Assimilation (Utilization). The process by which the growth of the protoplasm is increased by the absorbed food is called **assimilation**. Amino acids are mostly utilized in synthesis of proteins. Proteins are used for growth, repair, *etc*. The fatty acids and glycerol recombine to form fat. Fat is stored in the fat bodies. Fat and glucose are mainly utilized in the production of energy to be used for various body activities.

Egestion. The undigested food passes into the hindgut. Here, specially in the rectum, water and mineral salts are absorbed. The food changes into almost solid faeces. Faeces is temporarily stored in the rectum and later on passed out in the form of small dry pellets through the anus.

Blood Vascular System

The blood vascular system is of **open type**, *i.e.*, the blood does not flow in the vessels or capillaries, but moves through the internal open spaces and comes in direct contact with the body organs. This system comprises the following.

Haemolymph (= Blood). It is a mobile connective tissue composed of *corpuscles* and a colourless fluid, the *plasma*. The corpuscles are somewhat amoeboid shaped and are of two types. The **proleucocyte** corpuscles are small, but having proprotionately large nuclei, which oocupy the main space of the cells. The second type of corpuscles, the **phagocytes**, are large, engulf bacteria, other harmful microbes and foreign bodies. The blood of cockroach, as that of

*Pepsin (Enzyme) is absent in invertebrates.

other insects, contains organic molecules which are converted from the ionised inorganic compounds. The blood has high concentration of dissolved organic phosphates, uric acid and trachealose —a characteristic of insects. In fact, **trachealose** is a non-reducing sugar agent. Another important feature of the blood/haemolymph is that it does not contain any respiratory pigment and therefore plays no role in respiration.

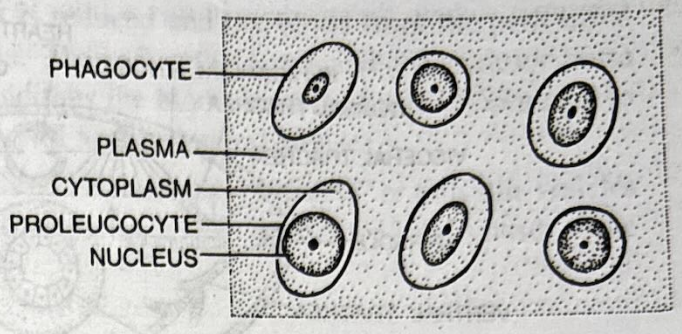


Fig. 7A.36. Haemolymph of cockroach.

The function of the blood can be summarised as : (i) it keeps the tissues moist; (ii) it ransfers the digested food to the various parts of the body; (iii) the phagocytes in the blood protect the body from the bacteria, germs and other harmful foreign bodies; (iv) The blood transports the nitrogenous waste material to the excretory organs ; and (v) the hormones secreted by the various endocrine glands reach the specific effector organs through the blood circulation.

Haemocoel. The body cavity of the cockroach is filled with blood or haemolymph and that is why it is referred to as **haemocoel**. In the thoracic and abdominal regions the haemocoel is divided by two horizontal partitions, the **diaphragms**, into three large spaces. These blood filled spaces are ; (i) **Dorsal** or **pericardial sinus** is present on the dorsal side below the terga and encloses the heart ; (ii) **Middle or perivisceral sinus** is the largest and encloses most of the viscera concerned with the systems of digestion respiration, excretion, reproduction etc. ; (iii) **ventral** or **perineutral sinus** lies on the ventral side above the sterna and encloses the nerve cord.

As already mentioned above the two diaphragms separate the blood-filled sinuses. The dorsal buldges upside and separates the pericardial sinus from the perivisceral sinus. The ventral diaphragm also projects upwards and separates the perivisceral sinus from the perineural sinus. Both the diaphragms are perforated by a number of apertures through which all the three sinuses are inter-connected. Some blood-filled spaces are also found in the head which are known as **head sinuses**.

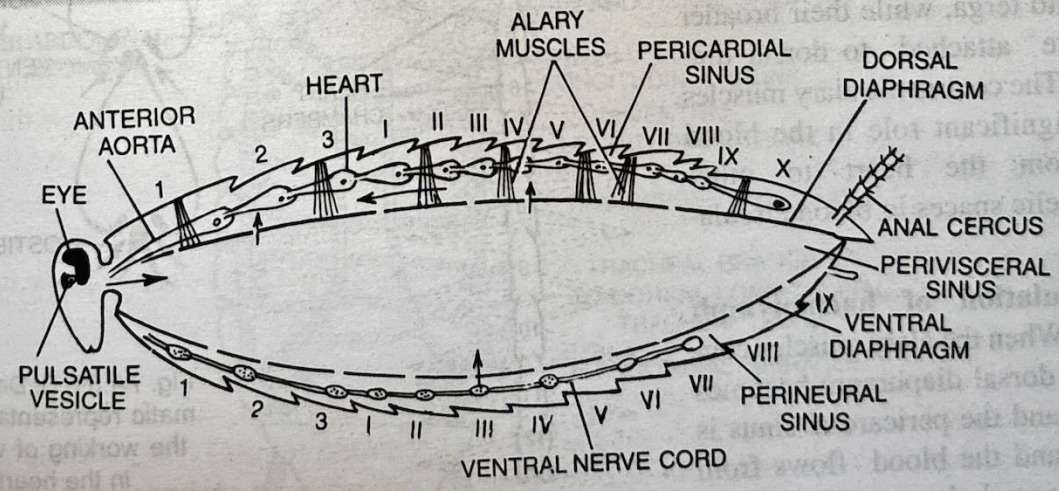


Fig. 7A.37. Diagram showing sinuses, diaphragms, heart, alary muscles, pulsatile vesicle, etc.

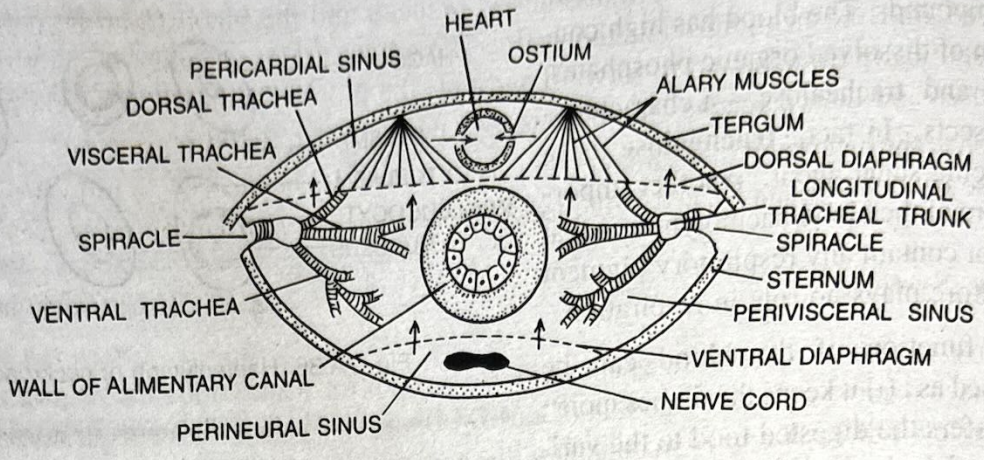


Fig. 7A.38. Diagrammatic T.S. of thorax of cockroach.

Heart. The heart or dorsal blood vessel lies mid-dorsally below the terga in the pericardial sinus. It consists of thirteen contractile chambers. The first three are present in the thoracic segments, while the remaining ten chambers are placed in the abdominal segments. The first chamber of the heart forms a single narrow tubular **anterior aorta** leading into the head sinuses. At the posterior end of each chamber, a pair of apertures, the **ostia**, are present laterally. The heart receives blood from the pericardeal sinus through ostia. Ostia are guarded by **auricular valves** to check the flow of blood from the heart to the pericardial sinus. All the chambers of the heart are inter-connected and their openings are guarded by the **ventricular valves**, to allow the blood flow anteriorly only. The last chamber is closed posteriorly. Heart of cockroach is **neurogenic** (heart beat is initiated by a nerve impulse).

There are present twelve pairs of fan shaped and triangular **alary muscles** ; their narrow ends are inserted into terga, while their broader ends are attached to dorsal diaphragm. The contractile alary muscles play a significant role in the blood flow from the heart to other haemocoelic spaces in blood circulation.

Circulation of haemolymph (blood). When the alary muscles contract, the dorsal diaphragm becomes flattened and the pericardial sinus is enlarged and the blood flows from the perivisceral sinus to the pericardial sinus through the apertures

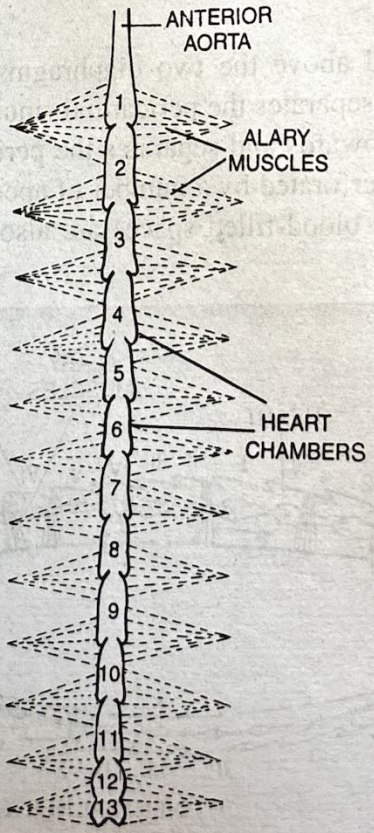


Fig. 7A.39. A, Heart and alary muscles of cockroach.

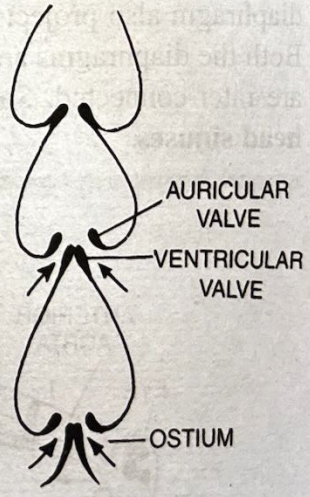


Fig. 7A.39. B, Diagrammatic representation of the working of valves in the heart.

present in the dorsal diaphragm. When the alary muscles relax, the dorsal diaphragm becomes arched so that the space of the pericardial sinus is reduced and the blood from the pericardial sinus is forced into the heart through the ostia. Thereafter the heart and the anterior aorta contract peristaltically from behind to forward and thus the blood from the heart is circulated to the head sinuses and then it reaches the perivisceral and perineural sinuses.

In addition to the main heart there are present very smal **accessory "hearts"** or **pulsatile vesicles** one at the base of each antenna located in the head, to pump the blood from the head sinuses to the antenna.

Respiratory System

Being terrestrial, cockroach utilizes atmospheric oxygen for respiration. The respiratory system of cockroach is more efficient than that of earthworm as there are definite respiratory organs. The atmospheric air directly comes in contact with the various organs of the body and therefore, the *blood is not used for respiration*. The respiratory system of cockroach includes (i) spiracles, (ii) tracheae, and (iii) tracheoles.

Spiracles. There are ten pairs of slit-like openings, the **spiracles** or **stigmata** situated on either side of the body wall. The first two pairs are known **thoracic spiracles** lying in thorax and the remaining eight pairs are called **abdominal spiracles** and are present in the first eight abdominal segments. The first pair is placed between the pro- and mesothroax and the second pair lies between meso- and metathorax. Each spiracle is surrounded by annular sclerite known as **peritreme** and leads into a chamber called **atrium**. The atrium has a valve (a closing device) and bristly plates (filtering apparatus) to keep out dust particles, parasites and water. From the atrium arise the main tracheae.

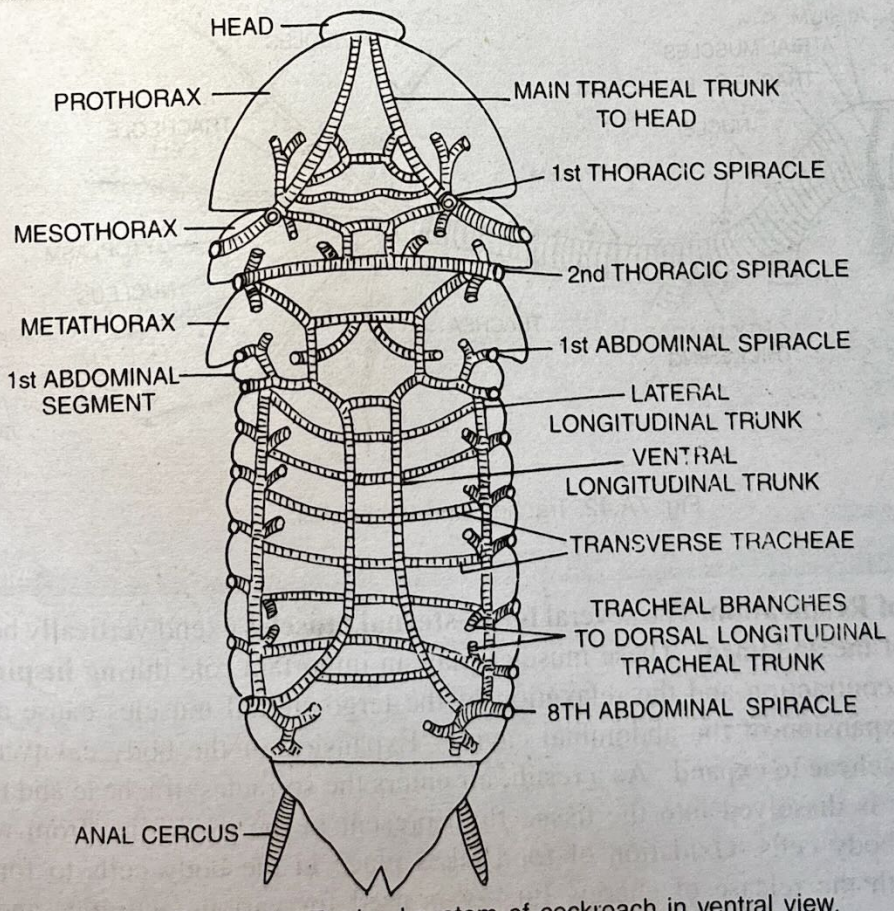


Fig. 7A-40. Tracheal system of cockroach in ventral view.

(II) **Tracheae**. The tracheae are silvery white ectodermal tubes formed by the invagination of the integument. Three pairs of **longitudinal tracheal trunks** are present all along the length of the body which are connected with each other with the help of **transverse tracheae.** From each tracheal trunk three branches come out. The dorsal branch is supplied to the dorsal muscles, the ventral branch to the nerve cord and the middle branch to the alimentary canal.

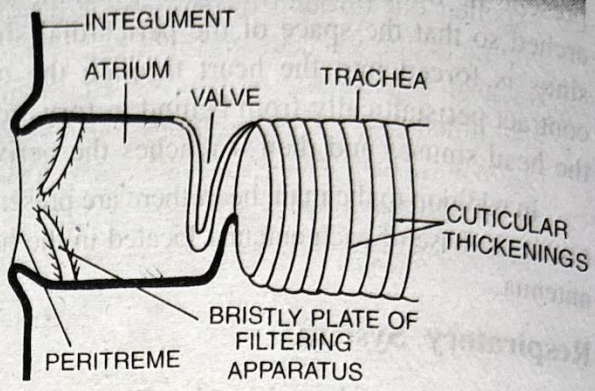


Fig. 7A.41. A spiracle with atrium, valve and a part of trachea.

The tracheal wall consists of an outer delicate single layered **syncytial epithelium** and inner cuticle. The inner spiral cuticular thickenings of the tracheae are known as **taenidia** or **intima**. The taenidia prevent the tracheae from collapsing. The lumen of the trachea is often seen to be filled up with a substance of unknown nature.

(III) **Tracheoles**. Ultimately, the trachea divides into fine branches known as **tracheoles**. They are devoid of taenidia and other chitinous structures. They terminate blindly in the tissues and contain a **tissue fluid** at the distal end which plays a significant role during the diffusion of the gases. The tissue fluid conveys respiratory gases to and from the cells of the body.

Tracheal system of respiration is also found in centipedes, millipedes, ticks and *Peripatus*.

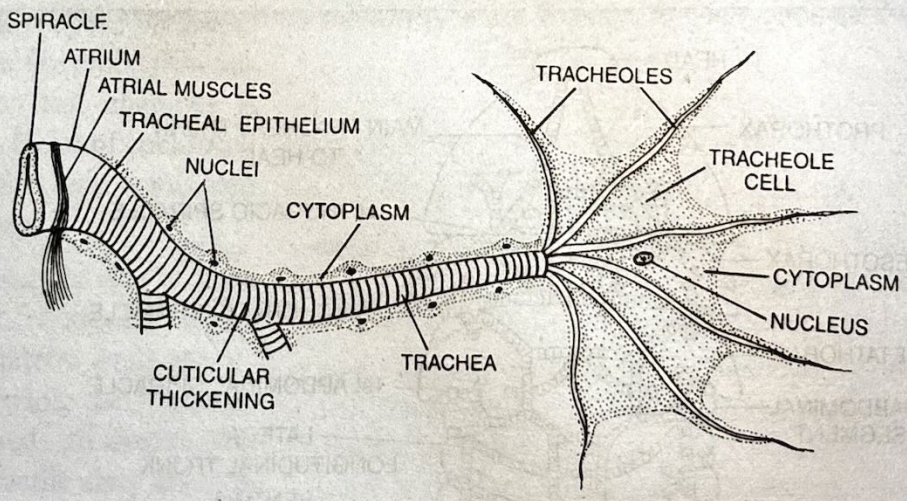


Fig. 7A.42. Trachea and tracheoles.

Mechanism of Respiration. The several **tergo-sternal muscles** exend vertically between the terga and sterna of the abdomen. These muscles play an important role during **inspiration** and **expiration**. The contraction and the relaxation of the tergo-sternal muscles cause a rhythmic contraction and expansion of the abdominal cavity. Expansion of the body cavity allows the space inside the tracheae to expand. As a result, air enters the spiracles, tracheae and tracheoles. Oxygen of the air is dissolved into the tissue fluid present in the tracheoles from which it is diffused into the body cells. Oxidation of food takes place in the body cells to form carbon dioxide, water with the release of energy. Energy is used for various activities and water is retained inside the body. The carbon dioxide either diffuses into the blood from where it is

expelled out through the cuticle or passed out during expiration. When the abdominal cavity contracts, the tracheal system also contracts. As a result the pressure of the foul air inside the tracheal system increases which causes the release of foul air. The first thoracic and the first abdominal spiracles remain open all the time whereas the remaining spiracles open during inspiration and close during expiration. According to another view, air is inspired and expired through all the spiracles.

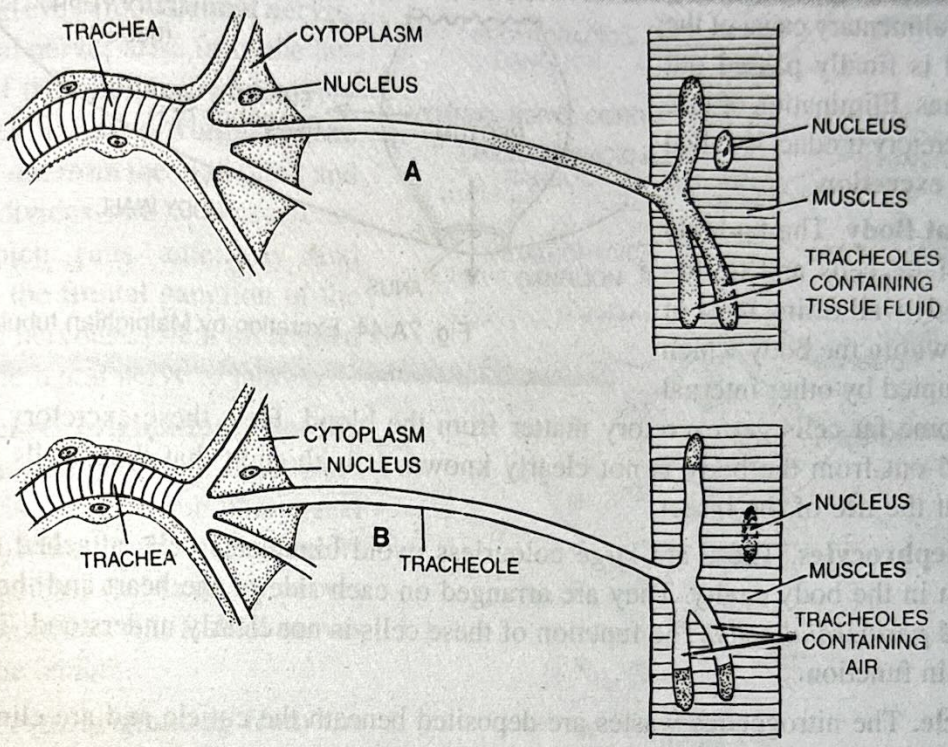


Fig. 7A.43. Mechanism of respiration. A, at rest. B, in activity.

When the cockroach is **at rest**, its oxygen requirement is less. In this condition some fluid from the cells passes into the tracheoles. The fluid dissolves the oxygen of the air present in the tracheoles. From the fluid oxygen diffuses into the cells, where it is consumed. Thus at rest, the tracheoles are filled with tissue fluid. When the cockroach is **active,** the osmotic pressure in tissue fluid increases due to high metabolic rate. Hence, the tracheoles remain empty and the inspired air directly reaches the tissue cells for gaseous exchange. Obviously, the rate of gaseous exchange increases during active life.

A considerable amount of carbon dioxide that dissolves in the haemolymph (blood of cockroach) passes out also by diffusion through the cuticle. It is due to the fact that the cuticle of cockroach is very permeable to carbon dioxide but not to oxygen.

Excretory System

It includes the following :

1. **Malpighian Tubules.**(Fig.7A.34 and 7A.44) These are long very fine unbranched yellow coloured blind tubules attached at the junction of mid and hind-gut . They are about 100-150 in number and arranged usually in six groups. The distal closed end of each tubule floats freely in the blood of perivisceral sinus and the proximal end open into the hindgut. These tubules extract metabolic wastes like potassium and sodium urate, water and carbon dioxide from the blood (7A.44). In the Malpighian tubules bicarbonates of potassium and sodium, water and uric

acid are formed. A large amount of water and bicarbonates of potassium and sodium are reabsorbed by the cells of Malpighian tubules and then transferred to the blood (haemolymph). Uric acid is carried to the alimentary canal of the insect and is finally passed out through anus. Elimination of uric acid as excretory product is called **uricotelic excretion**.

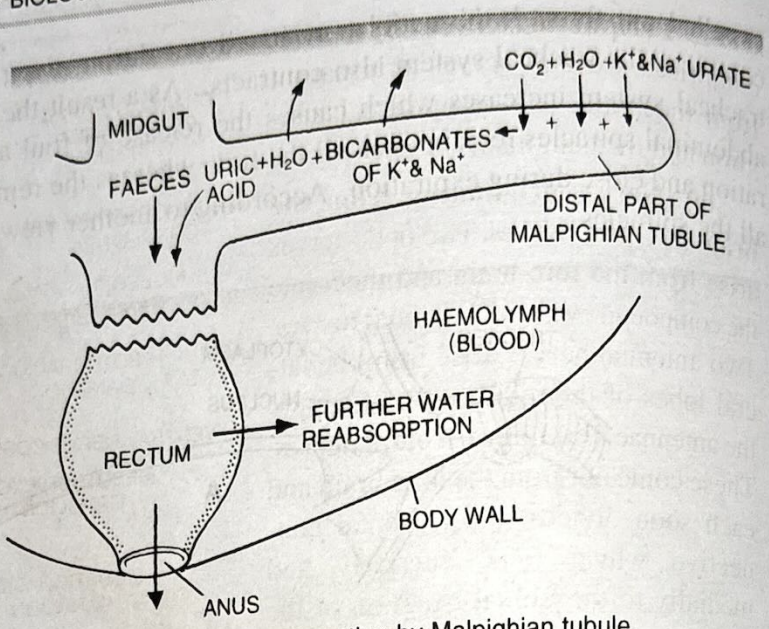


Fig. 7A.44. Excretion by Malpighian tubule.

2. **Fat Body**. The fat body consists of fat cells and lie below the body wall filling most of the space within the body which is not occupied by other internal organs. Some fat cells get excretory matter from the blood. How these excretory products are discharged out from the body is not clearly known. It is thought that these cells remain there throughout the life of the insect.

3. **Nephrocytes**. These are large colourless ovoid binucleate cells attached to the dorsal diaphragm in the body cavity. They are arranged on each side of the heart and hence they are also called *pericardial cells*. The function of these cells is not clearly understood. They may be excretory in function.

Cuticle. The nitrogenous wastes are deposited beneath the cuticle and are eliminated from the body during moulting (ecdysis).

Nervous System

The nervous system of cockroach is divisible into three groups. *Central Nervous System*, *Peripheral Nervous System* and *Sympathetic Nervous System*.

1. **Central Nervous System**. It consists of the following parts :

(i) **Brain** (Supraoesophageal ganglion). It lies above the oesophagus in the head. It is differentiated into fore-brain, mid-brain and hind-brain. It is formed by the fusion of three pairs of ganglia.

(ii) **Circumoesophageal connec-tives**. From either side of brain is given off a short broad circum-oesophageal connective ventrally and posteriorly around the oesophagus. They meet the sub-oesophageal ganglion.

(iii) **Sub-oesophageal ganglion**. It is actually formed by the fusion of three pairs of ganglia. It is in the form of white mass lying below the oesophagus in the head region. The brain, circum oesophageal connectives and sub-oesophageal ganglion constitute a nerve ring which lies in the head capsule.

(iv) **Ventral nerve cord**. A double ventral nerve cord extends from the sub-oesophageal ganglion ventral to the alimentary canal. It bears *three* **thoracic** and *six* **abdominal ganglia**. The three thoracic ganglia are situated in the pro-, meso-, and meta-thoracic segments. The six abdominal ganglia are situated in the first, second, third, fourth, sixth and seventh segments of the abdomen. The first five ganglia are more or less similar but the sixth abdominal ganglion is large.

2. **Peripheral Nervous System**. It comprises various nerves originating from the brain, sub-oesophageal ganglion and the ganglia of the nerve cord.

(a) Nerves originating from the brain (i) **Optic Nerves.** Two optic nerves arise from the fore-brain and innervate the compound eyes. (ii) **Antennal nerves.** Two antennal nerves arise from the lateral lobes of the mid-brain and supply the antennae. (iii) **Labro-frontal nerves.** These come out from the hind brain and each soon divides into a frontal connective which runs anteriorly and medially to the frontal ganglion of the sympathetic nervous system (described later) and the labral nerve to labrum.

(b) Nerves originating from the sub-oesophageal ganglion. Three pairs of nerves arise from the sub-pharyngeal ganglion. (i) **Mandibular nerves** innervate the mandibles. (ii)**Maxillary nerves** supply the maxillae. (iii) **Labial nerves** innervate the labium.

(c) Nerves originating from the ganglia of the ventral nerve cord. From the pro-, meso-, and meta-thoracic ganglia arise six, five, and five paired nerves respectively. Each of the anteriormost nerve from the meso-thoracic ganglion runs to the fore-wing; similarly another nerve from the meta-thoracic ganglion passes to the hind wing. The first abdominal segment is innervated by a pair of nerves from the meta-thoracic ganglion, while the second, third, fourth, firth and the sixth abdominal segments are supplied by the nerves arising from the first, second, third, fourth and fifth abdominal ganglia respectively. The sixth abdominal ganglion gives rise to several nerves to the remaining segments.

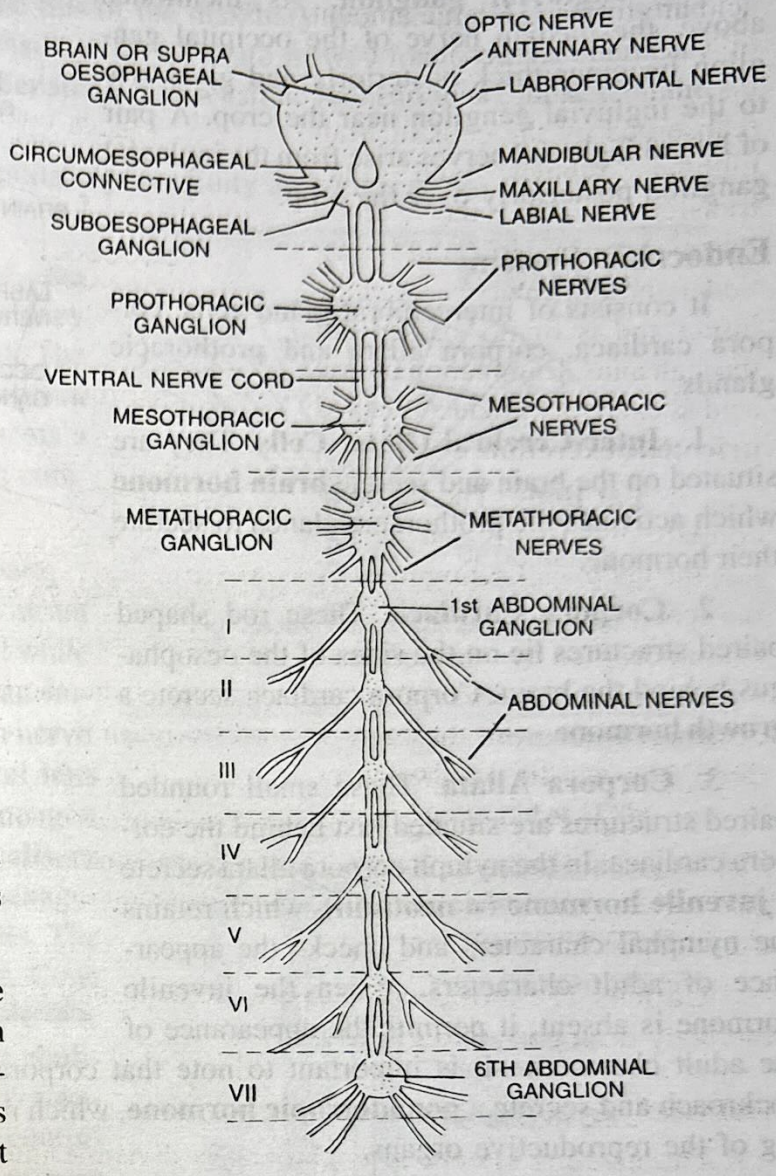


Fig. 7A.45. Central and peripheral nervous systems of cockroach.

3. **Sympathetic Nervous System**. It comprises the following ganglia and nerves :

(i) **Frontal ganglion**. It lies on the dorsal wall of the pharynx in front of the brain. It is connected with the hind brain by the frontal connectives. A frontal nerve arise from the frontal ganglion anteriorly to the frontal region. The recurrent (visceral) nerve runs from the frontal ganglion posteriorly above the oesophagus.

(ii) **Occipital ganglion.** After running a short distance, the recurrent nerve becomes thickened to form the occipital ganglion. Three nerves arise from the occipital ganglion. The two lateral ones are called occipital nerves : each runs to the corpus cardiacum (Endocrine gland) of its side. The median one, the recurrent nerve passes posteriorly on the oesophagus and forms *ingluvial ganglion* near the crop.

(iii) **Ingluvial ganglion.** As mentioned above, the median nerve of the occipital ganglion becomes thick posteriorly and gives rise to the ingluvial ganglion near the crop. A pair of lateral ingluvial nerves arise from the ingluvial ganglion posteriorly over the crop.

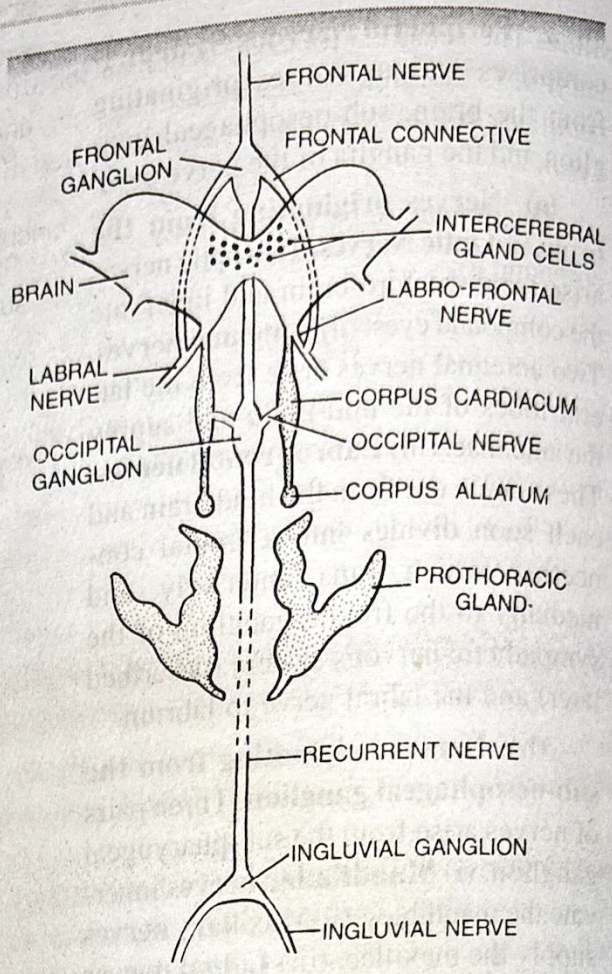


Fig. 7A.46. Sympathetic nervous system and endocrine glands of cockroach.

Endocrine System

It consists of intercerebral gland cells, corpora cardiaca, corpora allata and prothoracic glands.

1. **Inter-Cerebral Gland Cells**. They are situated on the brain and secrete **brain hormone** which activates the prothoracic glands to secrete their hormone.

2. **Corpora Cardiaca.** These rod shaped paired structures lie on the sides of the oesophagus behind the brain. Corpora cardiaca secrete a **growth hormone**.

3. **Corpora Allata**. These small rounded paired structures are situated just behind the corpora cardiaca. In the nymph corpora allata secrete a **juvenile hormone (= neotinin)**, which retains the nymphal characters and checks the appearance of adult characters. When the juvenile hormone is absent, it permits the appearance of the adult characters. It is important to note that corpora allata again becomes active in adult cockroach and secrete a **gonadotropic hormone**, which regulates the development and functioning of the reproductive organs.

4. **Prothoracic Glands**. These large irregular paired glands are located in the prothorax and secrete a hormone, the **ecdyson** to control **ecdysis** (moulting of the body wall) of the nymph. These glands degenerate after metamorphosis.

Sense Organs

Cockroach has several types of sense organs (= receptors). Except the photoreceptors (= eyes), all other receptors, occur in the skin and are called **sensillae**. The sensillae occur in the epidermis of the body wall. A sensilla has a modified **sensory cell** innervated by a nerve fibre, trichogen cell and tormogen cell. The secretion of trichogen cells form bristles and spines. The tormogen cell forms socket. Sensillae are of the following types :

(1) **Tactile Sensillae**. They occur all over the body, but are more abundant on the antennae, tibiae of legs and cerci. They respond to touch. (2) **Gustatory**

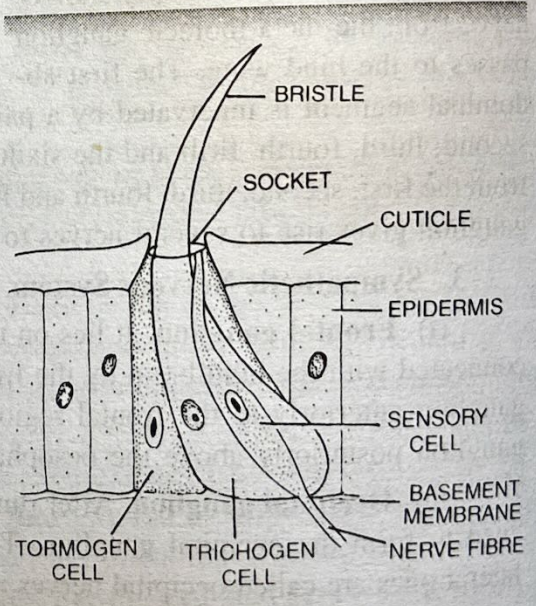


Fig. 7A. 47. A sensilla.

Sensillae. The sensillae for taste occur on the tips of the maxillary and labial palps and on the epipharynx. (3) **Olfactory Sensillae**. The sensillae for smell are mainly found on the antennae, and maxillary and labial palps. (4) **Auditory Sensillae**. The sensillae for hearing are located on the anal cerci.

The antennae, perhaps also bear sensillae for humidity and temperature.

Compound Eyes

The two compound eyes occupy a large area on each side of the head. Each eye is black, kidney shaped and bears about 2000 facets externally. The facets are transparent and more or less hexagonal biconvex areas. Each facet actually represents a visual element, the ommatidium. Thus, each compound eye contains about 2000 **ommatidia**.

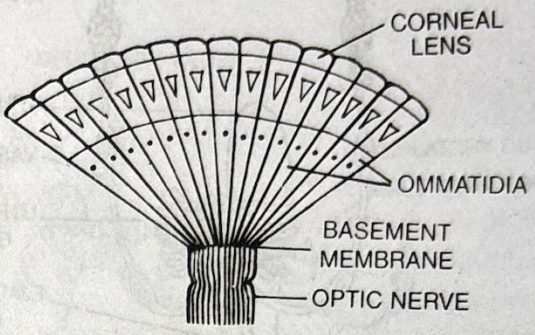


Fig. 7A.48. V.S. of compound eye of cockroach.

An ommatidium consists of two parts : **diopteric** and **receptive**. The diopteric part is meant for focussing light rays coming from an object while the receptive part converts the image into an impulse which is conveyed to the brain through nerve fibres. The diopteric part consists of **corneal lens** (transparent cuticle, acting as lens), two **corneagen cells**, a **crystalline cone** and four **cone cells** or **vitrellae**. The corneal lens is biconvex and hexagonal cuticular secretion of two corneagen cells. The crystalline cone is secreted by four cone cells. Cone cells are surrounded by **iris pigment sheath**. The receptive part is made up of spindle shaped **rhabdome** secreted by eight **retinular cells** or **retinulae**. The inner end of each retinular cell is continued into a nerve fibre, the **axon** which pierces through the basement membrane and joins the optic nerve. The **retinular pigment sheath** surrounds the region of retinular cells.

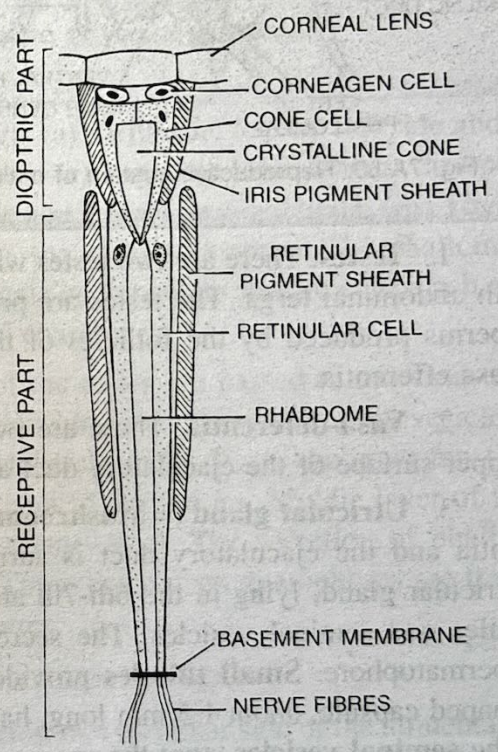


Fig. 7A. 49. V.S. of an ommatidium.

In cockroach, the light rays which enter obliquely fall on the iris pigment sheath and are absorbed. With the result, only those rays of light which enter an ommatidium running parallel to its long axis, come to a point on its rhabdome. Thus the image seen by the eye is formed by several points of light lying side by side, one in each ommatidium. Such an image is known as the **apposition image**. It is clear and detailed and forms in **mosaic vision**.

The **fenestrae** or **ocellar spots** located near the compound eyes are regarded undeveloped simple eyes by some and functional by others because they are sensitive to light.

Reproductive System

The cockroaches are **dioecious** (**unisexual**) animals. They exhibit sexual dimorphism, *i.e.*,

male and female individuals can be distinguished externally. The female cockroach bears broad abdomen, brood pouch, but lacks anal styles, as present in the males.

Male Reproductive System (Fig. 7A.50). The reproductive system of male cockroach consists of the following parts.

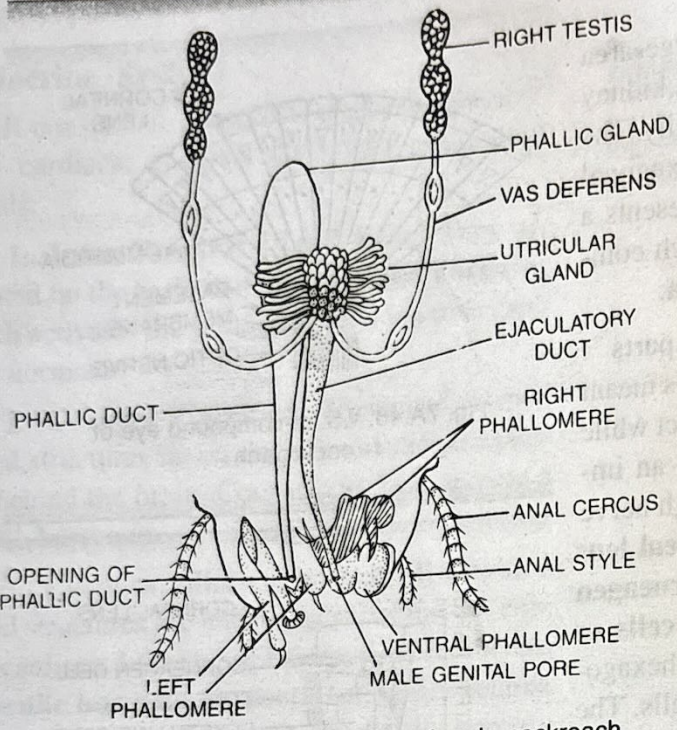


Fig. 7A.50. Reproductive system of male cockroach.

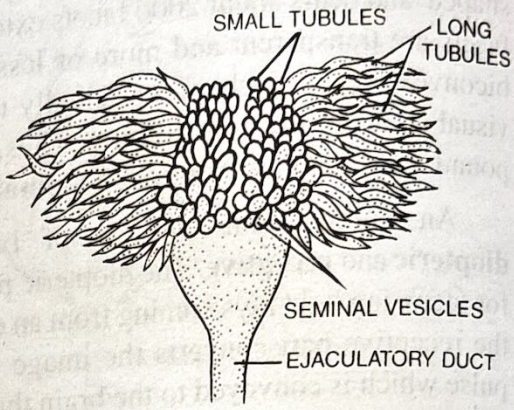


Fig. 7A.51. Utricular gland of male cockroach.

1. **Testes**. There are two testes which occupy dorsolateral position just beneath the 4th to 6th abdominal terga. The testes are prominent in young insects, but get reduced in adults. The sperms produced by the follicles of the testes are transferred to the vas deferens through the vasa efferentia.

2. **Vasa-deferentia**. These are two fine ducts which arise from the testes and open in the upper surface of the ejaculatory duct at the base of the mushroom-shaped utricular gland.

3. **Utricular gland (= Mushroom shaped gland** Fig. 7A.51). The junction of the vasa-deferentia and the ejaculatory duct is surrounded by a mushroom-shaped gland, which is called utricular gland, lying in the 6th-7th abdominal segments. It consists of long tubules, small tubules and seminal vesicles. The secretion of the **long tubules** forms the innermost layer of spermatophore. **Small tubules** provide nourishment to the sperms. Spermatophore is a pear-shaped capsule, about 1.5 mm long, having a three-layered wall and containing spermatic fluid. The **seminal vesicles** store the sperms.

4. **Ejaculatory duct**. The base of the utricular gland leads into an elongated muscular tube, the ejaculatory duct. The latter opens to the outside by an opening, the **male genital pore** lying close to ventral phallomere. The secretion of ejaculatory duct forms the middle layer of spermatophore. The spermatophores are passed outside through the gonopore.

5. **Phallic gland (= Conglobate gland)**. It is a large elongated sac-like structure which lies beneath the utricular gland and the ejaculatory duct. It tapers posteriorly and terminates into a duct near the male gonopore on the left phallomere. The secretion of phallic gland forms the outer most layer of the spermatophore.

6. **Phallomeres** or **Male gonapophyses** or **External genitalia**. There are three chitinous structures that surround the male gonophore. These are right, left and ventral phallomeres. (i) **The right phallomere**. Its front part is formed of two **opposing plates** and the hind part consists of curved **serrate lobe** which bears two large and pointed teeth like processes at its free end, several small teeth like processes along its border and a **hook** at its basal part.

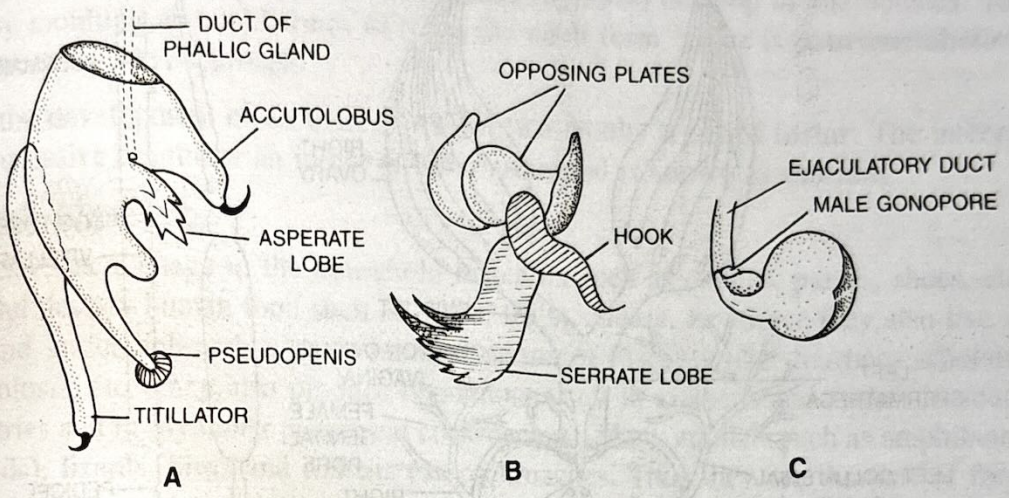


Fig. 7A.52. Male gonapophyses or phallomeres.
A, Left phallomere. B, Right phallomere. C, Ventral phallomere.

(ii) **The left phallomere**. It consists of four parts (a) **Titillator**. It is on left side and bears a hook. (b) **Pseudopenis**. It has a swollen bulb-like apex. (c) **Asperate lobe**. It bears the opening of phallic gland. (d) **Accutolobus**. It is on the right side and bears a terminal hook. (iii) **The ventral phallomere**. It consists of a broad plate and bears the male gonophore. The phallomeres are helpful in the transfer of the spermatophore from male cockroach to female cockroach and their some structures are used to open the female genital chamber.

The sperms produced by the sperm follicles of the testes are passed to the vasa-efferentia which refer to the vasa-deferentia. The vasa-deferentia transfer them to seminal vesicles where they are stored for some time. The secretion of peripheral tubules forms the inner most layer of the spermatophore. Small tubules provide nourishment to the sperms. Middle layer of the spermatophore is formed by the secretion of the ejaculatory duct. The secretion of phallic gland forms the outer most layer of the spermatophore. Three layered spermatophores are transferred to the female genital chamber by the male phallomeres.

Female Reproductive System. It consists of the following organs :

1. **Ovaries**. There are a pair of yellowish ovaries, one on either side of the alimentary canal. They are embedded in the fat bodies from the 4th to the 6th abdominal segments. Each ovary consists of **eight ovarioles** or **ovarian tubules**. Each ovariole has three distinguishable portions. (i) **Terminal Filament** is the anterior thread-like part of the ovariole. All the filaments of the eight ovarioles of each ovary are united to form a ligament and the ligaments of both ovaries meet in the middle line and get attached to the fat bodies. (ii) **Egg Tube** lies next to the terminal filament. It can be further distinguished into the anterior **germarium** containing the germ cells and a posterior **vitellarium** in which the germ cells (ova) get matured. (iii) **Pedicel** is a short tube which receives the opening of the egg tube. Pedicel of the eight ovarioles of each side open separately into the oviduct of that side. The pedicels provide a passage for the transference of ova from the egg tube to the oviduct. Eggs of cockroach are **centrolecithal** (yolk is located at the centre).

2. **Oviducts.** All the pedicels of the ovarioles of each ovary unite to form a short tubular and muscular structure, known as oviduct. Each oviduct receives ova from the ovarioles of its side and passes them to the next organ, the common oviduct.

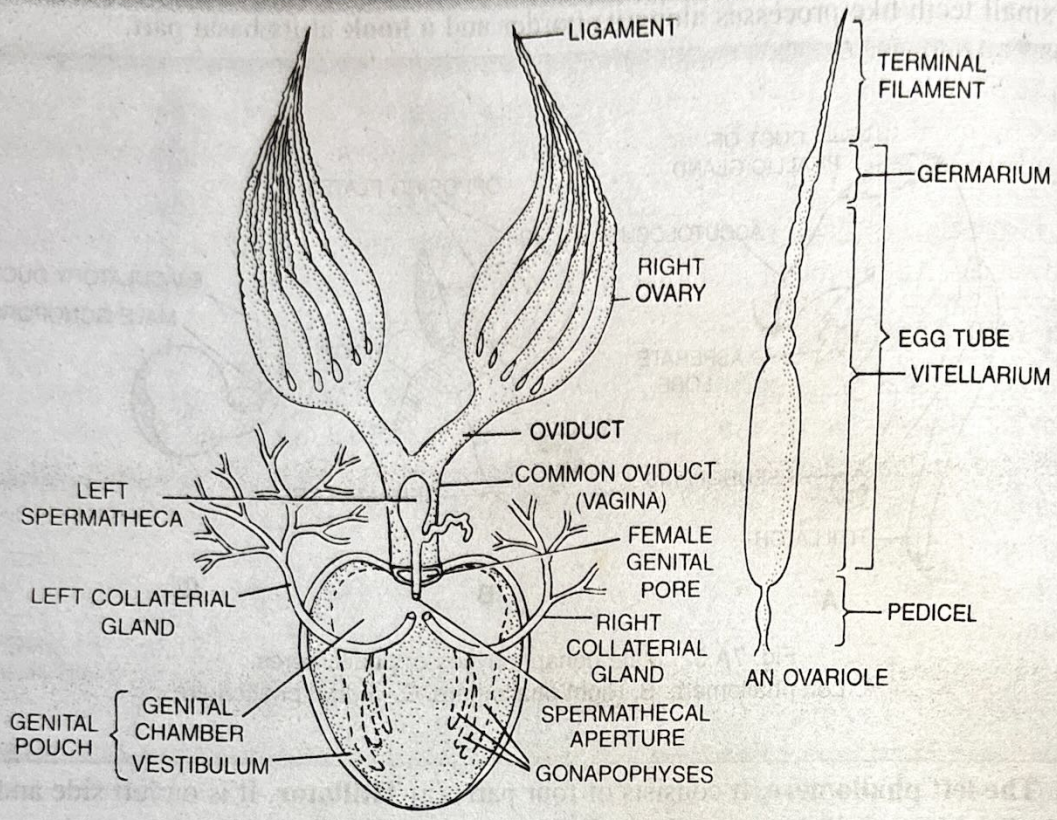


Fig. 7A.53. Reproductive system of female cockroach.

3. **Common Oviduct (= Vagina).** The two oviducts run posteriorly and unite to form a short wide common oviduct. The latter opens into the genital chamber by a vertical slit, the **female genital pore**.

4. **Genital pouch.** It encloses a boat shaped cavity. The front part of this cavity lies close to the female genital pore and hence called the **genital chamber**, while the posterior part is called **vestibulum** or **oothecal chamber**, because during the breeding it contains ootheca, a structure which contains 14-16 eggs (fertilized ova).

5. **Spermathecae.** These are a pair of sacs of unequal size, lying in the 6th abdominal segment. Left one is larger and stores the sperms received from the male during copulation. Right spermatheca is non-functional. Both the spermathecae open by a common duct into the genital chamber.

6. **Colleterial glands.** They are two very much branched tubuler glands, which are unequal in size and embedded in the fat. The left gland is large. Both the glands open independently on the dorsal side of the genital chamber. The secretion produced by these glands forms the oothecal case of the ootheca.

7. **Gonapophyses.** The six chitinous plates, the phallomeres, surrounding the female genital pore, are termed as gonapophyses. There is a pair of anterior gonapophyses and two pairs of posterior gonapophyses which function as **ovipositors**. The latter are used to carry eggs to the oothecal chamber.

The male and female cockroaches come together by their posterior ends and with the help of the male phallomeres, the spermatophores are transferred to the genital chamber of the female

where the sperms are liberated from the spermatophores and reach the left spermatheca slowly. The eggs come from both the ovaries alternately into the common oviduct and pass through the female gential pore into the genital chamber where they are fertilized by the sperms coming from the left spermatheca. The secretion of colleterial glands form the egg case of the ootheca. The ootheca is placed by female cockroach in dark and warm region. The placement of ootheca is called **oviposition**. On an average, a female produces 9–10 oothecae, each containing 14–16 fertilized eggs in two rows. Thus 14–16 young cockroaches (nymphs) develop in one ootheca. The nymph grows by moulting about 13 times to reach the adult form. There is **paurometabolous** (gradual) **metamorphosis** in cockroach.

A stage in the development of an insect between two moults is called **instar**. The interval between two successive moults of an insect or other arthropod is known as **stadium**.

Interaction with Mankind

Cockroaches cause damage to the household materials such as clothes, purses, shoes. etc. They also eat and destroy human food such as bread, fruits, cheese, etc. Since they also live in sewage pipes and gutter holes, they carry harmful germs of diseases like diarrhoea, cholera, typhoid, tuberculosis, etc. They also produce obnoxious smell in kitchens and stores. In south American countries and in Myanmar people eat cockroaches. Many animals such as amphibians (*e.g.*, frogs, toads), lizards, birds and rodents eat cockroaches. Thus they are the part of food chain. Cockroaches are used as experimental animals as they can be obtained easily without causing much ecological imbalance.

RANA TIGRINA (The Common Indian Frog)*

Systematic position

Phylum	—	Chordata
Subphylum	—	Vertebrata or Craniata
Section	—	Gnathostomata
Super Class	—	Tetrapoda
Class	—	Amphibia
Order	—	Anura
Family	—	Ranidae
Genus	—	*Rana*
Species	—	*tigrina*
Common name	—	Common Indian Frog

The frog is selected as a type animal to introduce the students for the study of vertebrates for the following reasons : (*i*) It is easily available and can be stored in the laboratory aquarium for a long period. (*ii*) The animal is easy to dissect and its anatomy and physiology can be conveniently demonstrated to the students because of the large size of the body organs. (*iii*) Moreover, it is one of the suitable animals for conducting physiological experiments. (*iv*) The study of frog reveals as to how the fish like animals got evolved into Amphibia, the first land vertebrates.

Habitat

Rana tigrina is the most widely distributed species in Northern India. Generally frogs are found in ponds, tanks, pools, ditches, etc. However, they may leave their aquatic habitat to come on land to hunt for their prey, which are mostly insects. Water habitat also helps the frog to run away from their natural enemies by jumping into water. Moreover, because the frog mainly respires through its skin, it occasionally goes into water to moisten its skin, which is very essential factor for such respiration. The frogs not only breed in water but also pass their early life history there. The frog is called an amphibious animal because it lives both in water and on land.

*For Competitive Exams.

Habits

1. **Locomotion**. The frog is very well adapted both for jumping and leaping on the land and swimming or floating in water.

(*i*) **Jumping and Leaping**. In resting position, the anterior somewhat upwardly inclined part of the body is supported by slightly twisted fore-limbs, while the hind limbs are folded in the form of 'z' position, which support the posterior part of the body and act as springs. Such sitting position is known as **squatting**. During jumping the hind-limbs suddenly extend while the fore-limbs hold the anterior part of the body in such a position as to adjust the body and guide the direction of each jump. Normally frog can jump up to three feet. When a frog jumps to a shorter distance, it is known as leaping.

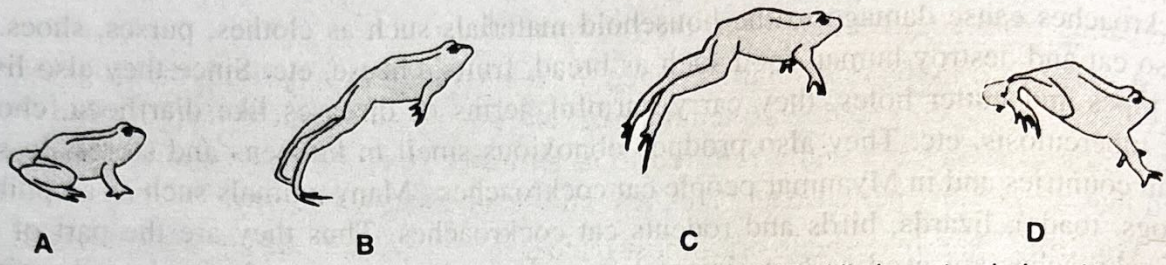


Fig. 7A.54. Leaping in Frog. (A) At rest hind limbs flexed. (B) Hind limbs extended pushing frog forward and upwards. (C) Fore limbs being extended beginning to draw up the hindlimbs. (D) Fore limbs extended to take first shock of landing : hind limbs drawn up.

(*ii*) **Swimming**. The alternate kicks of the hind-limbs push the webbed toes against water, thereby providing the force for swimming. After each swimming stroke, the fore-limbs are kept back and in case the frog stops swimming, the body and the hind-limbs remain in a straight position. Due to the long size of the hind-limbs and webbed nature of the toes they work like oars of a boat. The fore-limbs are also useful to the frog in swimming by providing some propulsion and guiding the direction for the forward movement. The boat-shaped body of the frog, mainly due to the absence of neck, is helpful in swimming.

It has been observed that sometimes the frog would simply float on the surface of the water keeping its snout outside the water for breathing.

2. **Feeding**. The adult frog is **carnivorous** and mostly feeds on insects and their larvae, spiders, earthworms and in some cases even their own larvae. It will capture only a moving prey and swallow it as a whole. When the prey is within a catching distance, the free posterior end of the tongue is shot out suddenly with much speed and is taken back into the buccal cavity with the prey sticking to it. The tadpole (larva) of frog is **herbivorous**.

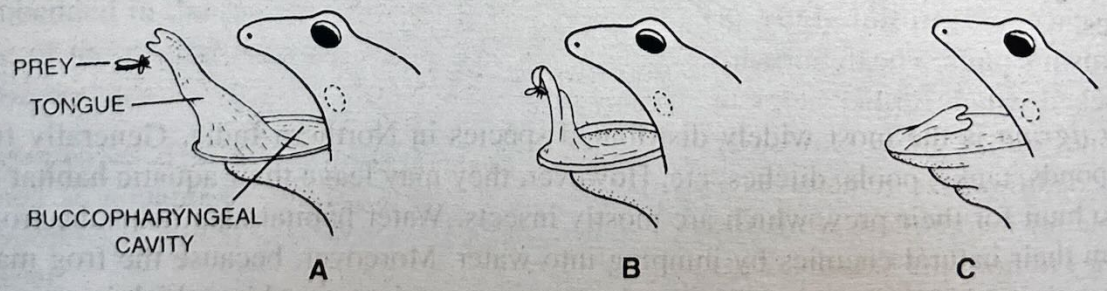


Fig. 7A.55. Diagrams to show frog catching a fly with its tongue.

3. **Croaking**. During the rainy season, which is also the breeding season of the frog, the frogs make peculiar sounds with the help of their vocal cords, known as **croaking**. The male frogs croak louder than the females, because in them the pitch of croaking is increased due to the presence of two **vocal sacs** situated one on each side of the floor of the throat. The vocal sacs act as resonators. The croaking is a mating call to attract the females.

4. **Exchange of gases**. It takes place through lungs, buccopharyngeal cavity and skin. However, in early tadpole, gills are the organs for exchange of gases.

5. **Hibernation**. Being a cold-blooded (**poikilothermal**) animal, the frog cannot withstand very cold weather and therefore, buries itself deep in the mud. During this period it lives in a dormant life of very slow vital body activities. Whatever little energy is required during this period it is obtained from the fat-bodies and from the stored glycogen of the liver, which had been stored in sufficient quantity earlier. The oxygen need of the animal is met with by respiration through skin. This **winter-sleep** is known as **hibernation**. With the coming of spring, the hibernating frogs come out and start their normal life.

6. **Aestivation**. In the mid summer, when the temperature is very high, the frogs escape to the places of concealment (mud, etc.) temporarily, but often coming out to feed themselves. This period of little activities is usually referred to as **summer sleep** or **aestivation**. However, it is believed that during this period frog takes rest and recuperates its energy.

7. **Moulting**. The frog sheds off almost once a month its skin during its active life in the form of small castings. This phenomenon is known as moulting.

8. **Metachrosis**. The frog is capable of changing its body colour, though gradually, with the change in its surroundings and climatic conditions. For example, when it lives in dark, damp and cool places due to intense heat or other factors, it becomes darker. Similarly when frog lives in hot atmosphere and bright sun-shine, it becomes lighter in colour. Incidentally by matching its colouration with the background, it can not only avoid its enemies but can catch its prey unnoticed. This capability of changing colour is known as **metachrosis.**

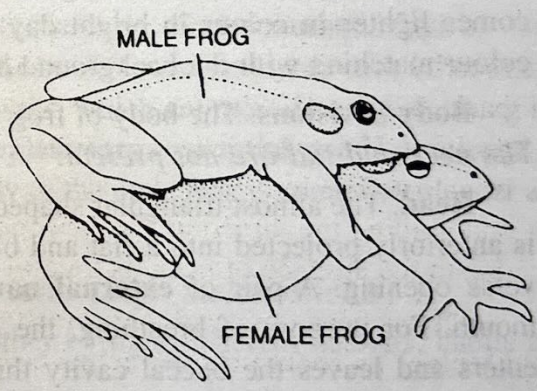


Fig. 7A.56. Frogs in amplexus

9. **Breeding**. The male frog can be easily distinguished by the presence of a pair of **vocal sacs**. The breeding season normally takes place during the rainy months from July to September. The male frog jumps on the back of the female frog and holds her tightly with the help of his fore-limbs behind her fore-limbs. Gripping of the female by the male is also very much aided by the presence of **nuptial pads** or **amplexusary pads**. The thumbs are inter-locked which further helps in the firmness of the grasp. Obviously in this condition, the female is responsible for locomotion, while the male tries to hold the balance. This sexual embrace is called the **amplexus**, which lasts for several hours. The term amplexus is used in place

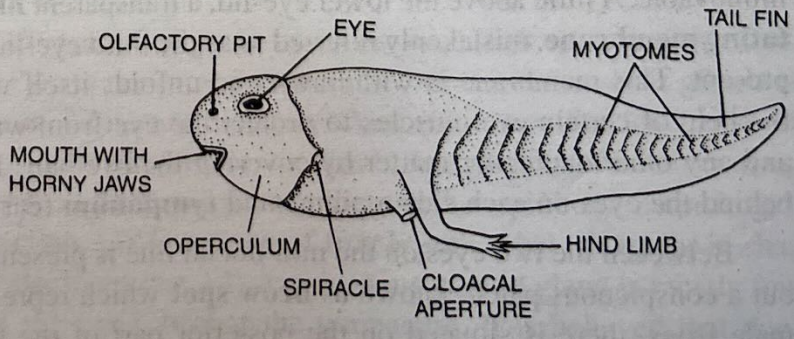


Fig. 7A.57. Tadpole of Frog.

of copulation, because male frog lacks copulatory organs. The female discharges its ova followed by the shedding of the sperms by the male to ensure fertilization, which takes place in water. Eggs of frog are **mesolecithal** and **telolecithal**. Mesolecithal eggs contain small amount of yolk. In telolecithal eggs the yolk is concentrated in the vegetal half. The fertilized ovum (egg) undergoes development to produce a fish-like tailed larva, the **tadpole**, which respires with the help of gills and feeds upon vegetable matter (herbivorous).

Morphology or External Characters

Shape, Size and Colour. The dorso-ventrally compressed body is somewhat ovoid in shape, having an almost triangular head. The fully grown adult frog may attain a length up to 17 cm. and its maximum breadth is about 8 cm. The soft skin of frog is devoid of any exoskeleton, such as scales, etc. Normally the colour of skin on the dorsal side is olive-green (sometimes olive brown even) mottled with dark spots. There is also visible a medium streak, usually known as dorsal line. The ventral side of the skin is not spotted and is creamish white (sometimes, even, slightly yellowish in colour). However, the colouration may change in response to varying surroundings. It assumes a dark shade in a dark surrounding and becomes lighter in colour in bright day light. Incidentally, this ability of the frog to change its colour matching with the background helps it to conceal itself from the enemies.

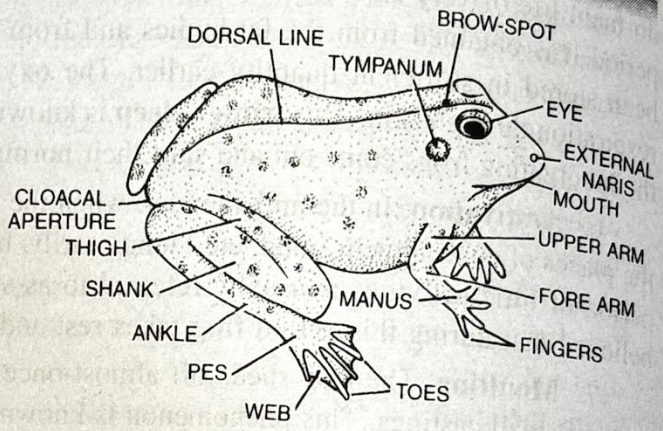


Fig. 7A.58. Frog. External characters.

Body Divisions. The body of frog is divisible into two parts only : the **head** and the **trunk**. *The neck and tail are not present.*

Head. The almost triangular shaped head is continued directly to the trunk portion. The head is anteriorly projected into a flat and blunt snout. The anteriorly placed **mouth** is a wide transverse opening. A pair of **external nares** (nostrils) are present at a short distance above the mouth. For purpose of breathing, the air containing oxygen enters and leaves the buccal cavity through these apertures. There is present a pair of dorso-laterally placed prominently bulging out **eyes** on the head. The eyes are protected by upper and lower **eye-lids**. **The upper eye-lid** is prominent, thick and slightly movable, while the **lower eye-lid** is vestigial and immovable. A little above the lower eye-lid, a transparent **nictitating membrane**, mistakenly referred to as the third eye-lid, is present. This membrane is withdrawn and unfolds itself with the help of certain eye muscles to protect the eye from water and any other damaging matter by covering the eye ball. Just behind the eyes on each side a pigmented **tympanum** (ear covering) is present.

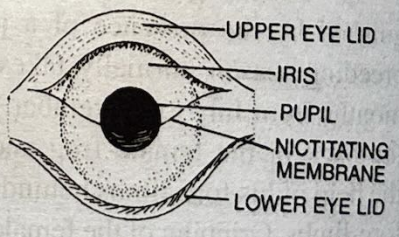


Fig. 7A.59. Eye of Frog as seen in the living animal.

Betweeen the two eyes on the mid-dorsal line is present a small circular and lightly coloured, but a conspicuous patch, known as **brow spot** which represents vestigial pineal eye. Only in the male frogs, there is situated on the posterior part of the throat a pair of somewhat bluish and wrinkled **vocal sacs**. The vocal sacs help in increasing the croaking which is referred to by some people as the "mating call".

Trunk. The neck being absent in frog, the head is directly continued into the trunk. The trunk comprises an anterior portion known as **thorax** and a posterior larger portion called **abdomen**. A pair of fore-limb and hind-limb is appended to the trunk. The forelimbs in both male and female frogs bear small **articular pads** dorsally at the joints of digits. The **fore-limb** consists of the proximal **upper arm** (brachium), the middle **fore-arm** (ante-brachium), **wrist** and a **hand** (manus) bearing four **fingers**. The finger corresponding to our **thumb** or **pollex** is rudimentary and invisible externally. During the breeding season, there develops a dark swelling on the inner finger of the male frog, the **nuptial pad** which helps the male frog in mating. Posteriorly and laterally placed, a pair of **hind-limbs** is appended to the trunk. The hind-limbs are much longer than the fore-limbs and more powerful. The **hind-limb** consists of proximal **thigh**, the middle **shank**, a long **ankle** and a **foot** (pes) bearing five **toes**. The first toe is called **hallux**. The toes are connected together by a thin membranous **web**, which helps the animal in swimming. A medially placed **cloacal aperture** is present for the outlet of faecal matter, urine and reproductive product.

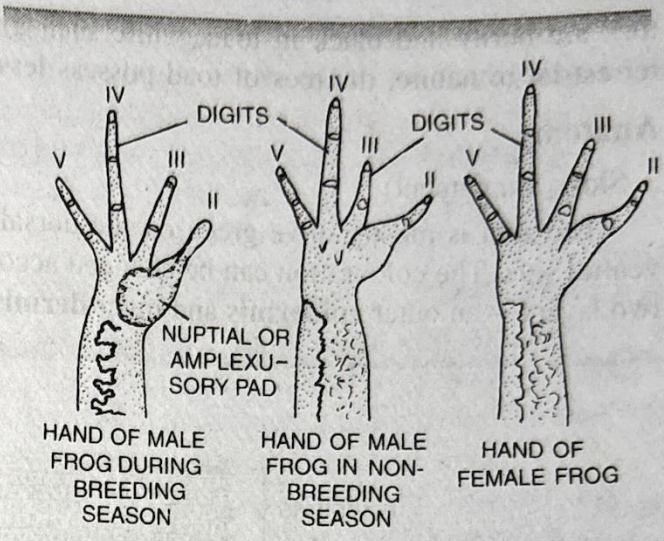


Fig. 7A.60. Hand of frog.

Sexual Dimorphism

This phenomenon means that the male and female animals can be distinguished by their external features. In case of frog the male and female can be differentiated from each other due to the following facts : (*i*) The male frog possesses vocal sacs, which are most developed during the breeding season. (*ii*) During the breeding season an **amplexusory** or **nuptial pad** is developed on first finger of each hand of the male frog. (*iii*) The body of the male frog is somewhat slender and darker in colour than the female frog.

How to distinguish frog (*Rana tigrina*) from a toad (*Bufo melanostictus*) ?

The two can be easily distinguished from each other by their different habitats, habits and some of the external features as stated below :

Habitat and Habits. (1) The frog mostly lives in water while the toad on the land, but the latter comes to water for breeding. (2) As a rule a toad is a nocturnal (active during the night) animal and the frog is mostly diurnal (active during the day). (3) The toad lays eggs in a line while frog lays eggs in a mass.

External Characters. (1) The frog is olive green in colour with dark spots and the toad is lightly brownish grey in colour. (2) Due to the presence of a large number of mucous glands and water habitat, the frog has a smooth moist and slippery skin and, since the toad is mostly confined to land life, a few mucous glands are present, its skin is dry, which is, moreover, rough, wrinkled and warty. The dry skin of toad is, therefore, not that much respiratory as in frog, the skin is rather more protective in function. (3) The snout of frog is somewhat triangular in shape, the snout of toad is almost semicircular in outline. (4) A poisonous parotid gland is mostly found in toad posteriorly on each side of the head, behind the tympanum. It is believed that due to these poisonous glands, the snakes avoid preying upon the toads. Parotid glands are absent in frog. (5) In toad the teeth are absent and the tongue is not bifid. (6) The tips of the fingers and

toes are horny and black in toad, while such a condition is absent in frog. (7) Being mostly terrestrial in nature, the toes of toad possess less developed webs.

Anatomy

Skin (Integument)

The skin is mostly olive green on the dorsal side and creamish white or yellowish on the ventral side. The colouration can be changed according to the surrounding. The skin consists of two layers— an outer **epidermis** and inner **dermis**.

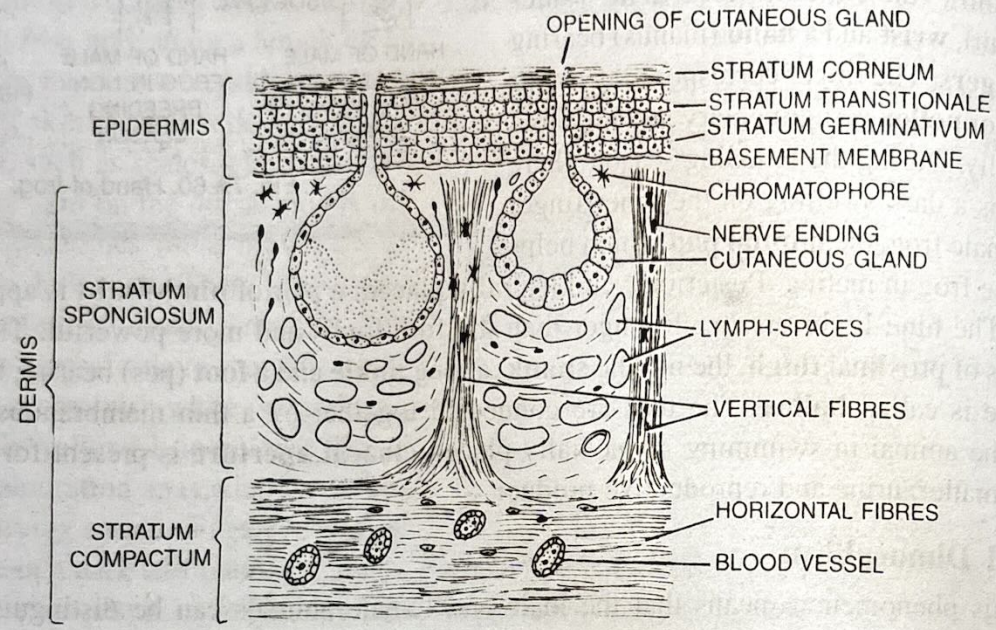


Fig. 7A.61. V.S. Skin of Frog.

Epidermis. It is the outer region of the skin, which is composed of stratified epithelium comprising many layers of cells. The epidermis is non-vascular layer. The innermost layer of the epidermis consists of columnar cells, which is called **stratum germinativum** or Malpighian layer, which undergoes active mitosis to produce new cells towards outside. Later on the cells shift to the outer surface and become extremely thin, inactive and ultimately dead to form the outermost layer of epidermis, which is termed as **stratum corneum**. The layers between stratum corneum and stratum germinativum are referred to by a common name of **stratum transitionale**. The stratum corneum is protective in function and is periodically cast off (moulting). This phenomenon, known as **ecdysis**, is affected by the secretions (**hormones**) of two ductless glands, the **pituitary and thyroid**. On the surface of stratum corneum, are present the openings of the cutaneous glands. The stratum germinativum rests on basement membrane.

Dermis. The thick dermis is placed below the epidermis and constituted by an upper bigger area: the **stratum spongiosum** and the lower smaller portion : the **stratum compactum**. The stratum spongiosum is composed of highly blood vascular network of loose fibrous connective tissues, therefore, spongy in nature and richly supplied by nerve fibres and contains many **lymph spaces**. The sensitivity of the skin is due to the presence of touch corpuscles and **nerve endings**. Just beneath the stratum germinativum there are present many scattered pigment cells (**chromatophores**) in the stratum spongiosum. The pigment cells are responsible for the colour of the animal. The chromatophores are of three types. (i) **Lipophores** are yellow fatty cells which have red and yellow pigment. (ii) **Guanophores** are specialized cells which contain white pigment called

guanine. (iii) **Melanophores** are black pigment cells which contain dark brown or black pigment, called melanin.

The olive greenish colour is due to the combined effect of these three pigments.

There are two kinds of glands in the stratum spongiosum : (i) **Mucous glands** are thick walled small in size and many in number. The mucous glands secrete a slimy fluid, the mucus, which makes the skin moist and slippery in nature, (ii) **Poison glands** are few in number and only infrequently present in frog, but mostly present in toads. These are thin walled and bigger in size and secrete a poisonous fluid, which protects these animals from their enemies. Both mucous and poison glands are formed by the stratum germinativum and invaginated below with their necks opening on the surface of the skin.

The inner region of dermis consists of compact dense connective tissue, known as **stratum compactum**. There are present many **horizontal** and some bundles of **vertical connective tissue fibres**. The vertical fibres invariably run up to the stratum spongiosum and may be sometimes supplied with muscles. They aid to the compactness and firmness of the skin. In addition, these vertical fibres by their contraction help in the squeezing out of cutaneous glands secretions. The stratum compactum is also supplied with nerves and blood vessels.

Functions of Skin

(1) Maintenance of a characteristic shape. (2) Protection from the mechanical injuries, etc. (3) Cutaneous respiration. (4) Absorption of water. (5) Mucous glands of the skin secrete mucus. (6) Frog cannot drink water, it absorbs water through skin. (7) Webs between the toes help in swimming. (8) Skin responds to external stimuli such as touch, temperature, etc. (9) Skin of frog can change the colour to match with the colour of external environment. The capability is called metachrosis. (10) Dermis forms certain dermal bones (nasal, frontal, etc.) of the skin. Teeth are also mainly formed from dermis.

Body Cavity (Coelom)

Definition. The space or cavity lined by parietal peritoneum externally and visceral peritoneum internally is known as **coelom** or **cavity**. Parietal peritoneum forms the innermost layer of the body wall, while visceral peritoneum lines the viscera externally.

Divisions. In frog it is a large and extensive cavity in the trunk region and encloses the viscera (soft internal organs) of the trunk. The coelom of frog is divisible into : (i) an anterior small **pericardial coelom** or **cavity** enclosing the heart and (ii) posterior spacious **abdominal** (pleuroperitoneal) **coelom** in which the rest of the internal organs lying in the trunk are lodged.

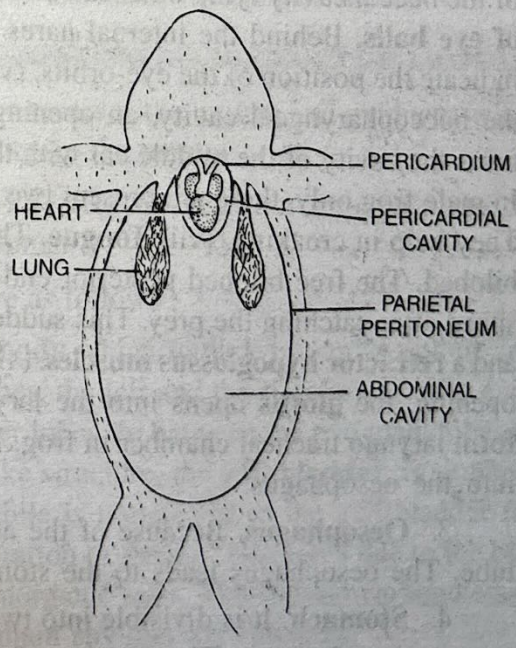


Fig. 7A.62. Coelomic cavities in frog.

Digestive System

The digestive system consists of the **alimentary canal** and the associated **digestive glands**.

Alimentary canal. The alimentary canal consists of the following parts.

1. **Mouth**. Mouth is a wide anteriormost opening leading to a spacious buccopharyngeal cavity. Mouth enables the frog to capture large prey. It is bounded by immovable upper jaw and movable lower jaw.

2. **Buccopharyngeal cavity** (Fig. 7A.63). It is so-called because the buccal cavity and pharynx have been merged into one cavity. The buccopharyngeal cavity comprises the following structures.

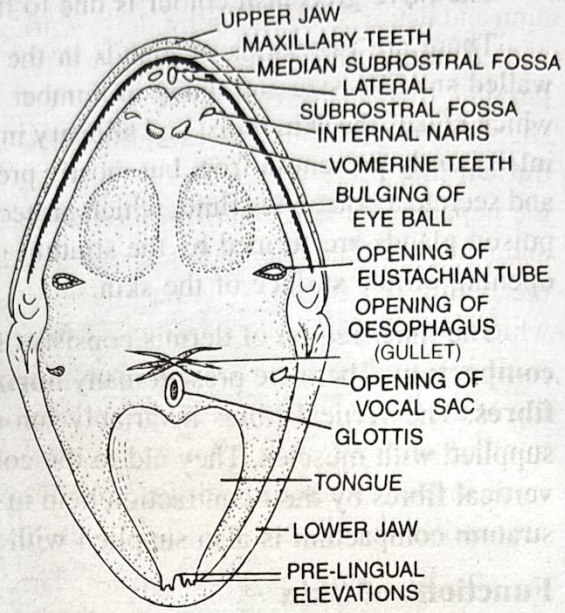


Fig. 7A.63. Buccopharyngeal cavity of male frog.

(i) **Teeth**. The teeth are absent on the lower jaw while the upper jaw bears similar small, backwardly directed conical teeth known as **maxillary teeth**. In addition there are present two patches of **vomerine teeth** one on each vomer bone, near the internal naris. All teeth are similar and are, therefore, known as **homodont**. If the teeth are broken or worn out, they are easily replaced many times. Such teeth are called **polyphyodont**. Unlike man, the teeth of frog are not lodged in sockets but fixed by an adhesive secretion, the **cement**. Such teeth are known as **acrodont**. The teeth of frog are not masticatory. They only help in injuring the prey and prevent its escape from the buccopharyngeal cavity. (ii) **Sub-rostral fossae and prelingual elevations**. Three depressions, the **subrostral fossae** can be seen behind the upper jaw. Three small elevated structures, called the **prelingual elevations** are placed at the tip of the lower jaw opposite to the subrostral fossae. These elevations get fixed into the subrostral fossae and help in closing the mouth firmly during exchange of gases. (iii) **Internal nares**. A pair of internal nares, in the form of two small openings are present on the roof of the buccal cavity lying outer to vomerine teeth. They help in exchange of gases. (iv) **Bulgings of eye balls**. Behind the internal nares are present two prominent bulgings of eye balls which indicate the position of the eye-orbits. (v) **Openings of Eustachian tubes**. On each lateral side of the buccopharyngeal cavity, an opening of the *Eustachian tube can be observed which connects the cavity of the middle ear with the buccopharyngeal cavity. (vi) **Openings of vocal sacs**. In male frog only, there are present two openings of the vocal sacs near the angles of lower jaw. They help in croaking. (vii) **Tongue**. The tongue is fixed in front but its hinder end is free and bilobed. The free bilobed posterior end can be thrown out and retracted backward with a great speed after catching the prey. This sudden action of the tongue is brought about by a **protractor** and a **retractor hypoglossus muscles**. (viii) **Glottis and opening of oesophagus (gullet)**. A slit like opening, the **glottis** opens into the laryngotracheal chamber. Larynx and trachea are fused to form laryngo tracheal chamber in frog. Medianly placed is a wide opening, the gullet, that leads into the oesophagus.

3. **Oesophagus**. Because of the absence of neck in frog, the oesophagus is only a short tube. The oesophagus leads to the stomach.

4. **Stomach**. It is divisible into two parts : (i) **Cardiac stomach**, the anterior larger part is present near the heart. The opening of the oesophagus into the cardiac stomach is guarded by a **cardiac sphincter**, a powerful ring of circular muscles, which prevents the backward flow of food. (ii) **Pyloric stomach** is a posterior narrow tapering part, which is separated from the duodenum by a muscular constriction, the **pyloric constriction** externally, which indicates the position of pyloric sphincter, which controls the entry of food into duodenum.

* Tube named after the name of **B. Eustachio**, Italian Physician.

5. **Small Intestine**. It is the longest part of the alimentary canal suspended by mesentery, and is divisible into duodenum and ileum. (a) **Duodenum**. It is a thin walled narrow tube which bends forwards parallel to the stomach to form a `U' shaped structure. Its internal lining is thrown into transverse folds. It receives the hepatopancreatic duct from the liver and pancreas. The duodenum passes into the ileum. (b) **Ileum**. It is narrow tube which is coiled in order to accommodate itself in a limited space. The internal lining of the ileum is also thrown into a large number of finger like branched projections known as **villi** which increase the absorptive surface area.

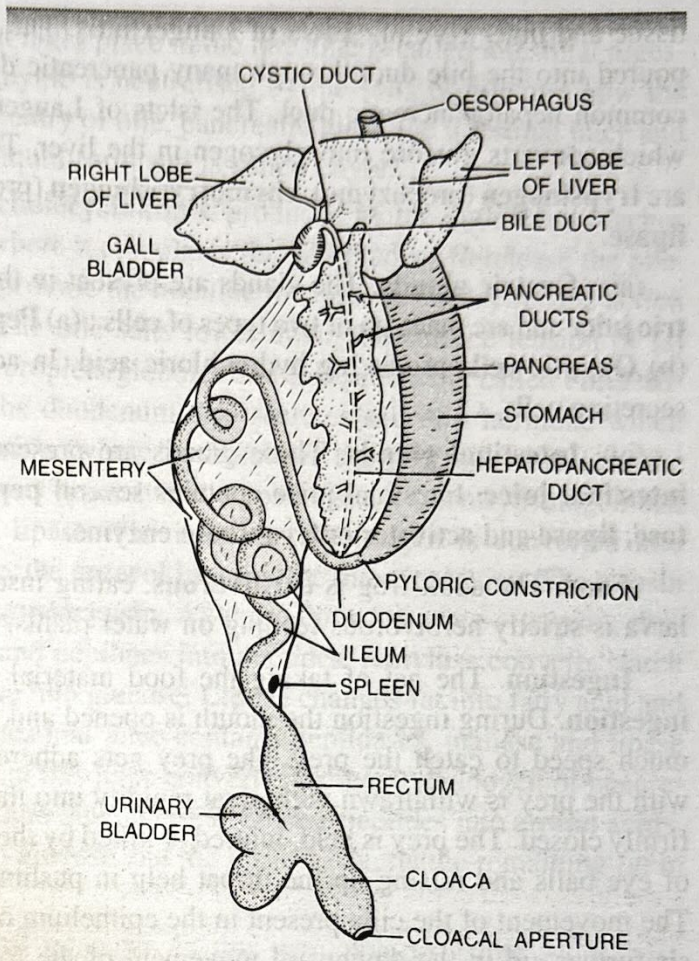


Fig. 7A.64. Alimentary canal (except buccopharyngeal cavity) of frog. Liver, gall-bladder, pancreas, spleen and mesentery are also shown.

6. **Rectum (Large Intestine)**. The ileum leads into a broad, thin walled short but wider tube, known as **rectum** or **large intestine**, suspended by a mesentery, the mesorectum. Posteriorly, it opens into the cloaca through an aperture known as **anus** which is guarded by an **anal-sphincter**. The rectum stores the faecal matter and water is absorbed by its wall.

7. **Cloaca**. It is the last part of the alimentary canal, which receives the rectum in both the sexes, but in female frog, the cloaca also receives the ureters and oviducts, while in the male the urinogenital ducts are received in addition to the rectum.

The urinary bladder also opens into the cloaca. The cloaca opens out through a cloacal **aperture**, situated at the posteriormost end of the abdomen.

Digestive Glands. In frog, the digestive glands are as follows :

(i) **Liver**. The liver is the **largest gland of the body** which is dark brown in colour and situated just behind the heart. It is composed of two lobes, the left and the right joined with each other. The left lobe is larger and divided into two smaller lobes. In between the two main lobes of the liver, a muscular, rounded, dark bluish green bag like structure, the **gall bladder**, is situated. The liver secretes a liquid, which is called **bile**. The bile is transferred to the gall bladder for storage through many **hepatic ducts**. The typical colouration of the gall bladder is due to the bile pigments present in it. The bile contains organic and inorganic salts. The sodium carbonate salt of bile makes it alkaline. The bile as such does not contain any digestive enzyme.

The gall bladder gives rise to a duct, the **cystic duct**, which also receives a few hepatic ducts from the liver directly. The cystic duct proceeds towards the duodenum as the **bile duct**. When the bile duct passes through pancreas, it receives some **pancreatic ducts** from the pancreas and opens into the duodenum as a common **hepato-pancreatic duct**.

(ii) **Pancreas**. It is a branched flat elongated pale yellow gland lying in mesentery extended in the loop between stomach and duodenum. The pancreas is made up of **lobules**, connective

tissue and inner core of *__islets of Langerhans__. The lobules produce **pancreatic juice** which is poured into the bile duct through many pancreatic ducts and finally reaches the duodenum via common hepatopancreatic duct. The islets of Langerhans secrete a hormone known as **insulin** which converts glucose into glycogen in the liver. The enzymes present in the pancreatic juice are **trypsinogen** (proenzyme), **chymotrypsinogen** (proenzyme), **peptidase, amylase, maltase** and **lipase**.

(iii) **Gastric glands**. The glands are present in the stomach. The gastric glands secrete **gastric juice** and are made up of two types of cells : (a) **Peptic cells** secreting **proenzyme, pepsinogen**, (b) **Oxyntic cells** producing hydrochloric acid. In addition there are also present many mucus secreting cells.

(iv) **Intestinal glands**. These glands are present in the small intestine which secrete the **intestinal juice**. Intestinal juice contains several **peptidases** such as tri and dipeptidases, **maltase, lipase** and activator **enterokinese** enzyme.

Food. The adult frog is **carnivorous**, eating insects, spiders, earthworms etc. However, its larva is strictly herbivorous feeding on water plants.

Ingestion. The act of taking the food material into the buccopharyngeal cavity is called **ingestion**. During ingestion the mouth is opened and the muscular sticky tongue is shot out with much speed to catch the prey. The prey gets adhered to the sticky tongue. The tongue along with the prey is withdrawn with great rapidity into the buccopharyngeal cavity and the mouth is firmly closed. The prey is held, injured or killed by the maxillary and vomerine teeth. The bulging of eye balls and raising up the throat help in pushing down the food towards the oesophagus. The movement of the cilia present in the epithelium of the buccopharyngeal cavity and **peristalsis** further aid in the downward movement of the food into the oesophagus. *The **peristalsis** is due to the alternate constrictions and relaxations of longitudinal and circular muscles present in tubular muscular organs like alimentary canal, bile duct, ureter, reproductive ducts, etc., passing from one end of the tubular organ to the other end.* During this, the contents of the tube are pushed onwards.

Digestion. Digestion is a process by which the non-diffusible food material is converted into diffusible form by the action of various digestive enzymes. The buccopharyngeal cavity and the oesophagus do not secrete any enzymes but help in moistening the food with their mucus. The latter helps in transferring the food particles into the stomach. The main components of the animal food matter are proteins, carbohydrates, fats and mineral salts, etc.

1. **Gastric Digestion**. Digestion that takes place in the stomach is known as gastric digestion. The walls of the stomach secrete a hormone, the **gastrin**, which stimulates the gastric glands to release the gastric juice. The gastric juice contains hydrochloric acid and a proenzyme **pepsinogen** and mucus. Hydrochloric acid converts inactive pepsinogen into active **pepsin**. The acid also provides the acidic medium, which is essential for the action of pepsin. The acid is antiseptic, killing harmful germs, which usually enter the alimentary canal along the food material. The pepsin converts proteins into proteoses and peptones. The carbohydrates and fats remain unaffected by the proteolytic enzymes.

In the stomach the food is stored for quite a long time. Due to the massive peristalsis of the stomach wall, the food is broken into smaller pieces and thoroughly mixed with the gastric secretions including the mucus. The food is now in a semi-liquid state known as **chyme**. The latter passes into the duodenum through pyloric sphincter at regular intervals.

* Spherical or oval bodies scattered throughout the pancreas named after the name of P. Langerhans, German Anatomist.

2. **Intestinal Digestion**. Digestion that takes place in the intestine is called intestinal digestion. In the duodenum, the acidity of the chyme is neutralised by the salts of bile and now the chyme becomes alkaline in nature. With the entry of bile, pancreatic juice, the intestinal juice and more of mucus, the food is now in a more liquid form and is called **chyle**.

(a) **Action of Bile**. A hormone, the **cholecystokinin**, produced by the duodenum reaches the gall bladder through blood circulation where it stimulates the gall bladder to release the bile. The bile contains no enzymes, but its salts provide the alkaline medium necessary for the action of the pancreatic and intestinal enzymes. The bile salts lower down the surface tension of fat material, which is then broken into fine fat droplets/globules and this process is called **emulsification**. (b) **Action of Pancreatic Juice**. The duodenum also secretes **secretin** hormone which reaches the pancreas through blood circulation, where it stimulates the pancreas to release the pancreatic juice. The pancreatic juice contains proenzymes trypsinogen, chymotrypsinogen and enzymes peptidase, amylase, maltase and lipase. The inactive trypsinogen is converted into **trypsin** by the action of an activator enzyme, the **enterokinase** of the intestinal juice. The trypsin converts inactive chymotrypsinogen into **chymotrypsin**. All these three enzymes— trypsin, chymotrypsin and peptidase change proteoses and peptones into peptides. **Amylase** converts starch into maltose. **Maltase** converts some maltose into glucose. **Lipase** changes fat into fatty acid and glycerol. (c) **Action of Intestinal Juice**. Intestinal juice contains peptidases, maltase and lipase enzymes. The enzyme enterokinase present in this juice converts inactive trypsinogen of pancreatic juice into trypsin. Many **peptidases** (tri and dipeptidases), change peptides into **amino acids**. Maltase changes the rest of the maltose into **glucose** and the lipase converts the remaining fat in **fatty acids** and **glycerol**.

The digestion is completed in the small intestine. In this way, non-diffusible foods, *viz.*, proteins, carbohydrates and fats are converted into diffusible forms (ultimate products of the digestive process) such as amino acids, glucose, fatty acids and glycerol respectively.

Absorption. It is a process by which the digested food diffuses into the circulatory system (blood and lymph) through the wall of the alimentary canal. The absorption starts from the stomach, whose mucous membrane absorbs water and mineral salts. Most of the absorption is done by small intestine. The wall of the alimentary canal is richly traversed by blood and lymph capillaries. The lymph capillaries of the intestine are known as **lacteals**. Amino acids, glucose, vitamins and water are absorbed into blood capillaries, while fatty acids and glycerol enter the lymph-capillaries. The rectum mainly absorbs water.

Egestion. Egestion is a process by which the unabsorbed food or faecal matters are passed out. The indigestible food comes to rectum by peristaltic action, where water is mainly absorbed. After that, the faecal matters are transferred to the cloaca and from there they are egested via cloacal aperture.

Functions of Liver

The liver has got great functional significance and, therefore, deserves special reference. Its various functions are mentioned below : (1) **Production of Bile**. The bile is secreted by the liver and stored in the gall bladder; it is used in the small intestine for digestion of food. (2) **Glycogenesis**. It means the conversion of excess of glucose into its *inert* state, glycogen, which is stored in the liver as reserve food. (3) **Glycogenolysis**. It means conversion of glycogen into glucose; it occurs, whenever there is a deficiency of glucose in the blood. (4) **Deamination**. The amino group (NH_2) is removed from the amino acids, resulting in the production of ammonia, which is converted into urea. The process by which the ammonia is converted into urea is called deamination. It is carried out by the liver cells. (5) **Detoxification**. The liver also converts toxic substances into

non-toxic products. The latter are subsequently excreted through the kidneys. (6) **Excretion**. The liver produces the excretory products such as urea and other nitrogenous wastes and bile pigments. (7) **Haemopoiesis**. During embryonic stage, the erythrocytes (red blood corpuscles) are produced by the liver. The tissues which form the blood corpuscles of vertebrates are called **haemopoietic tissues** and the process of the formation of corpuscles is **haemopoiesis**. In adult frog, blood protein, the fibrinogen is also produced by the liver cells. (8) **Destruction of red blood corpuscles**. The old worn out red blood corpuscles are broken down in the liver cells and transferred to the alimentary canal along with the bile. (9) **Blood clotting**. The liver produces blood proteins, **heparin** and **fibrinogen**. Heparin checks the clotting of blood inside the blood vessels while fibrinogen helps in the blood clotting when any part of the body is injured. (10) **Phagocytosis**. The liver cells kill harmful bacteria and eliminate foreign substances by producing antitoxins and antibodies. This function of the liver is known as phagocytosis. (11) **Production of Heat**. Due to the high metabolic activities of the liver enough heat is generated which is so essential for maintaining optimum blood temperature. (12) **Synthesis of Vitamin**. The liver synthesizes the important vitamin A, which is produced from a raw substance, the **ceratin**. (13) **Formation of Lymph**. It is very important centre for the formation of the lymph. (14) **Storage of Iron and Copper**. It also helps in the storage of iron and copper. (15) **Storage of Excess Water**. Liver stores excess of water temporarily and, therefore, regulates the volume and viscosity of blood.

Respiratory Organs and Modes of Respiration

Being amphibious nature, the frog can utilize free oxygen and also oxygen dissolved in water. The adult frog respires in three different manners : (i) *Cutaneous* or *skin respiration ;* (ii) *Buccopharyngeal respiration ;* (iii) *Pulmonary or lung respiration.*

1. **Cutaneous respiration.** The skin of frog provides an extensive surface for the exchange of gases. It is thin, richly supplied with blood and kept moist by the mucus and water. The cutaneous respiration is always carried out. During hibernation (winter sleep) and aestivation (summer sleep) it is the only method of respiration in frog.

2. **Buccopharyngeal respiration.** It occurs when the animal is on the land or partially immersed in water. There are present two external nares situated at the tip of the snout. Each external naris (nostril) leads into a nasal chamber which opens into the buccopharyngeal cavity by an internal naris. During this mode of respiration, the mouth and glottis are tightly closed while the nares are kept open. There are two sets of muscles which operate the mechanism of buccopharyngeal respiration. These muscles are sternohyal muscles and petrohyal muscles. (i) **Sternohyal muscles** are attached by one end to the sternum and at the other end to the hyoid apparatus. (ii) **Petrohyal muscles** are attached at one end to the hyoid apparatus and at the other end to the auditory capsule (prootic bone). Buccopharyngeal respiration occurs when the frog is on land or partially immersed in water.

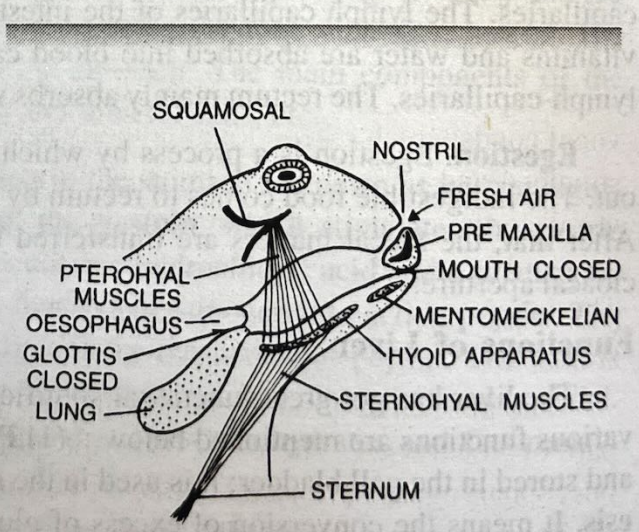


Fig. 7A.65. Showing two types of muscles in frog.

3. **Pulmonary respiration.** It is less frequent than the cutaneous and buccopharyngeal respiration. Respiratory path includes external nares, nasal chambers, internal nares,

buccopharyngeal cavity and glottis. The glottis opens into the laryngotracheal chamber. This chamber leads posteriorly to the lungs through a pair of apertures. The lungs are two delicate, elastic, pinkish, ovoid, thin walled hollow sacs lying on either side of the oesophagus. Each lung looks like a honey-comb. The inner surface of the lungs is divided by a series of partitions, the septa into many small cavities known as **alveoli**. The wall of the alveoli are richly supplied with blood capillaries. *Exchange of gases takes place through alveoli*. During pulmonary respiration, the mouth is tightly closed. The sternohyal and petrohyal muscles play very important role in the mechanism. Pulmonary respiration is less frequent than the cutaneous and buccopharyngeal respiration. It occurs when need for oxygen is increased.

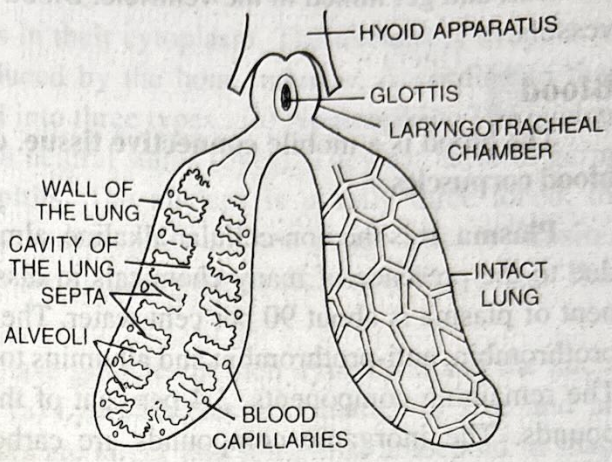


Fig. 7A.66. Lungs of frog. Laryngotracheal chamber and position of hyoid also shown. Left side lung is in section to show internal structure.

Sound Producing Organ

A thin walled **laryngotracheal chamber** is the sound producing organ in the frog. It corresponds to the larynx and trachea of higher animals. Since the neck is absent in the frog, the larynx and trachea are combined to form the laryngotracheal chamber. It lies below the pharynx between the **posterior cornua** of the **hyoid apparatus**. Anteriorly, it opens into the buccopharyngeal cavity by a slit like opening, the **glottis**, situated at the floor of the pharynx. Posteriorly, it leads into the lungs by a pair of apertures. The skeleton of the laryngotracheal chamber consists of a **cricoid** and two **arytenoid cartilages**.

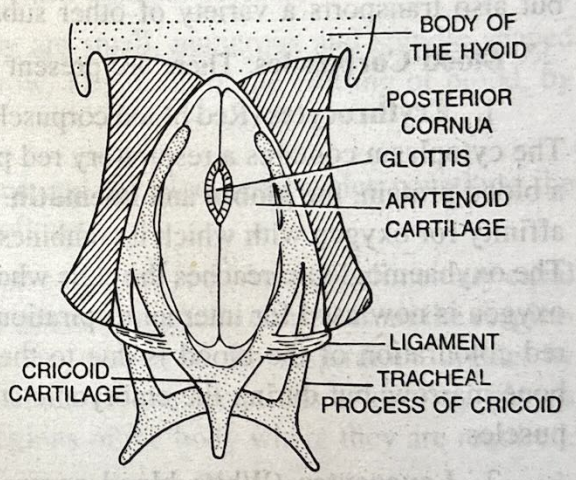


Fig. 7A.67. Part of Hyoid Apparatus and cartilages of Laryngotracheal Chamber.

There is also present a pair of elastic bands, the **vocal cords** which extend longitudinally across the laryngotracheal chamber. These cords can be stretched and relaxed by the **laryngeal muscles** attached to the cartilages of this chamber. The vocal cords are the true sound producing organs. A narrow slit like gap, the **rima-glottis** is present between the free inner edges of the vocal cords, which helps in the production of sound. The inner edges of the vocal cords, which lie freely, get vibrated when air from the lungs is expelled out forcibly to produce a characteristic sound (croak).

The male frogs produce louder and prolonged sound than the females because males have a pair of vocal sacs. These sacs are the pouches of the skin on the throat, opening into the buccopharyngeal cavity and acting as **resonators**. When the air is expelled out from the lungs the vocal sacs are inflated with air to raise the pitch of the sound in the male frog. Thus, the male frogs croack more loudly than the females.

Circulatory System

The circulatory system of frog consists of blood vascular system and lymphatic system.

Blood Vascular System. It is of **closed type** as the blood flows in the blood vessels. It

represents **single circulation**. It means both the oxygenated and the deoxygenated blood enters the heart and get mixed in the ventricle. Blood vascular system comprises blood, heart and blood vessels.

Blood

The blood is a mobile **connective tissue**, composed of a fluid, the **plasma** and the cells, the **blood corpuscles**.

Plasma. It is the non-cellular alkaline, almost colourless fluid, however, it is slightly viscous due to the presence of many chemicals in dissolved or suspended condition. The main component of plasma is about 90 per cent water. The plasma proteins like serum, globulin, fibrinogen, prothrombin, anti-prothrombin and albumins together constitute about 6–7 per cent of the plasma. The remaining components, 3.4 per cent of the plasma consists of inorganic and organic compounds. The inorganic compounds are carbonates, bicarbonates, chlorides, phosphates and sulphates of sodium, potassium, calcium, magnesium and iron. The respiratory gases such as oxygen and carbon dioxide are also dissolved in the plasma. The organic compounds are glucose, amino acid, fat, fatty acids, glycerol, vitamins, urea, uric acid, enzymes, hormones, antibodies, antitoxins, etc.

The plasma is not only concerned with carrying blood corpuscles from one place to the other but also transports a variety of other substances.

Blood Corpuscles. There are present three types of cells in the blood plasma :

1. **Erythrocytes** (Red blood corpuscles). These are large, oval and biconvex nucleated cells. The cytoplasm contains a respiratory red pigment, known as **haemoglobin**, which is made up of a blood protein, the **globin** and **haematin**. Haematin contains iron. The haemoglobin has a great affinity for oxygen with which it combines to form an unstable compound, the **oxyhaemoglobin**. The oxyhaemoglobin reaches the cells where oxygen gets separated from haemoglobin. This free oxygen is now used for internal respiration. In this way, the erythrocytes help in respiration. The red colouration of the blood is due to the haemoglobin. The erythrocytes are produced by the bone marrow, but during the embryonic stage, liver and spleen also manufacture red blood corpuscles.

2. **Leucocytes** (White blood corpuscles). Their number is also numerous but less than

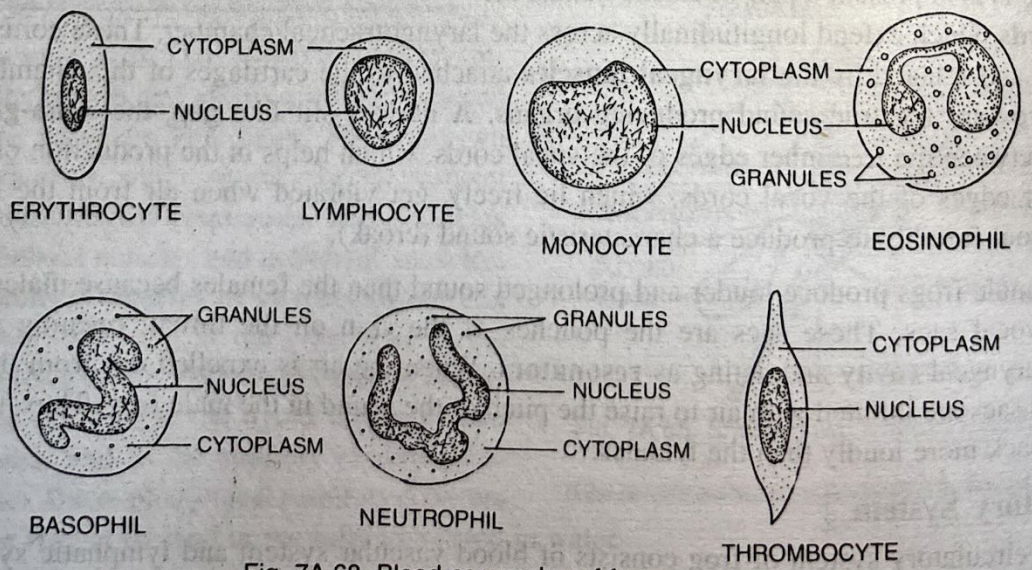


Fig. 7A.68. Blood corpuscles of frog.

erythrocytes. Each has an amoeboid shape with a colourless cytoplasm and a definite nucleus. They can change their shape like *Amoeba*. The leucocytes are of two types :

(i) **Granulocytes**. They contain granules in their cytoplasm. The nucleus is irregular or lobed or subdivided. The granulocytes are produced by the bone, marrow. According to their staining property the granulocytes can be divided into three types : (a) **Neutrophils**. The nucleus is many lobed and their granules are stained with neutral stains (dyes). They eat harmful germs and, therefore, phagocytic in nature. (b) **Basophils**. The nucleus is usually three lobed, the granules of these cells get stained with basic stains. Basophils are non-phagocytic. (c) **Eosinophils**. The nucleus is two lobed and the granules are stained with acidic stains like eosin. They are also phagocytic.

(ii) **Agranulocytes**. These cells do not have granules in their cytoplasm and the nuclei are rounded. The agranulocytes are of two types : (a) **Lymphocytes** are smaller in size and are produced by spleen and thymus; (b) **monocytes** are larger and somewhat amoeboid in shape and phagocytic in nature. Monocytes are produced by bone marrow.

The leucocytes produce antibodies, which destroy the disease causing foreign bodies like germs, etc. They protect the body of the animal.

The leucocytes in general and their lymphocytic types in particular are capable of squeezing out through the wall of the blood capillaries into the extra vascular regions.

3. **Thrombocytes (Spindle-shaped cells)**. They are small, numerous and spindle shaped nucleated cells. They are produced by the bone marrow. They help in the clotting of blood, by producing the thrombin enzyme.

Functions of Blood. The functions of the plasma and the blood corpuscles constitute the function of the blood. These can be summarized as follows :

(1) **Transport of food material**. Blood transports the digested food from the alimentary canal to the cells of the body. (2) **Transport of respiratory gases**. Oxygen is carried from the respiratory organs to the tissues and carbon dioxide from the tissues to the respiratory organs by blood. (3) **Transport of hormones**. The hormones, which are the secretions of ductless glands (endocrine glands), are carried by blood to various regions of the body where they are required. (4) **Transport of nitrogenous waste products** (excretory products). The nitrogenous waste products are transferred from the liver to the kidneys by blood for excretion. (5) **Protection against diseases**. The phagocytic leucocytes protect the animal from the harmful germs by eating them. Some leucocytes also produce anti-bodies. (6) **Regulation of body temperature**. The blood regulates the temperature of the body by carrying heat from the heat producing organs to heat losing organs, so that body temperature remains roughly the same in every part of the body. (7) **Prevention of excessive loss of blood**. When any part of the body is injured the coagulating property of the blood prevents the excessive loss of blood by producing a clot. (8) **Helps in healing**. After the clot has been formed, the blood provides the repair material which heals the wound. (9) **Maintenance of *p*H**. The plasma proteins of blood act as a buffer system and prevent a shift in *p*H of blood. RBCs also discharge similar function to certain extent. (10) **Water balance**. Blood maintains the water balance upto a constant level by bringing about constant exchange of water between circulating blood and tissue fluid.

Clotting of Blood

Clotting is an important property of blood when it comes in contact with air. During this vital process a series of reactions take place. In this process six factors are involved.

(i) **Fibrinogen** is a blood protein. (ii) **Prothrombin** is an inactive state of **thrombin**. (iii) **Thromboplastin** is an enzyme formed at the time of clotting by disintegration of thrombocytes and the surrounding tissue cells. (iv) **Heparin** is an intra-vascular anticoagulant present in the plasma. (v) Ca^{++} ions are present in the blood plasma. (vi) **Tryptase** is another enzyme of blood.

Vitamin K is also believed to facilitate the clotting of blood. The various stages in the sequence of clotting are given below :

Thromboplastin + locked prothrombin →prothrombin.

$$\text{Prothrombin} \xrightarrow[\text{Tryptase}]{Ca^{++}} \text{Thrombin}$$

Fibrinogen + Thrombin →Fibrin (Insoluble clot)

Fibrin + Blood cells →Blood clot

The fine insoluble fibrils of fibrin cross each other to form a network. In the meshes of this network, the blood corpuscles are trapped to plug the meshes. In this way, the outgoing flow of them is blocked and the loss of blood is stopped. Heparin checks the clotting of blood inside the blood vessels.

Heart

The heart, is a modified blood vessel to receive and distribute the blood.

Location. The heart is situated midventrally in the thorax in between the two lungs, just anterior to the liver. The heart is protected by the pectoral girdle ventrolaterally and by vertebral column dorsally.

Pericardium. The heart is enclosed in a delicate transparent two layered sac, the **pericardium**. The outer layer of the sac is called **parietal pericardium** and inner layer is known as **visceral pericardium**. In between the two layers, a space, the **pericardial cavity** is present, which is filled with a **pericardial fluid**. The pericardium protects the heart from the shocks, and mechanical injuries and also allows its free movements.

Structure of Heart. After removing the pericardium, the external characters of the heart are clearly seen. The heart of frog is **three chambered**, *viz.*, two auricles and a single ventricle.

In addition to the auricles and ventricle, there are also two other associated structures, known as **sinus venosus** and **truncus arteriosus** (= **conus arteriosus**).

The two thin walled auricles are separated from each other by the **interauricular septum**. The sinus venosus opens into right larger auricle through **sinu-auricular aperture** which is guarded by a pair of **sinuauricular valves.** It only allows the blood to flow towards the right auricle. The common **opening of pulmonary veins** is present in the smaller left auricle. The opening is not guarded by any valve.

Both the auricles open into a single ventricle by a common wide **auriculo-ventricular aperture**, which is guarded by a valve, the **auriculo-ventricular valve** bearing four flaps— one dorsal, one ventral and two lateral in position. The free edges of these flaps project into the ventricle and are connected to the wall of the ventricle with fine contractile but tough thread-like structures known as **chordae tendineae**. The chordae tendineae regulate the movement of the auriculo-ventricular valve so as to allow the blood to pass from the auricles into the ventricle and further prevent the backward flow of the blood into the auricles. The ventricle is a muscular and thick walled chamber, the inner surface of which is projected into ridges, the **columnae carneae**. The latter divide the cavity of the ventricle into smaller spaces, known as **fissures**.

The right side of the ventricle opens into truncus arteriosus on the ventral side. At the place from where the truncus arteriosus arises from the ventricle, a row of three pocket shaped **semilunar valves** is present. These valves allow blood flow from the ventricle to the truncus arteriosus. The latter consists of a proximal muscular part, the **pylangium** and the distal part, the **synangium**. A row of the three semilunar valves separates the pylangium from the synangium. The pylangium part is further divided vertically into two incomplete chambers by a **spiral twisted valve**. The right chamber is called **cavum aorticum** and the left **cavum pulmocutaneum**. The spiral valve is a flap of tissue running vertically in the pylangium and is attached with the middle valve of the anterior row of the three semilunar valves. The spiral valve is free ventrally and posteriorly.

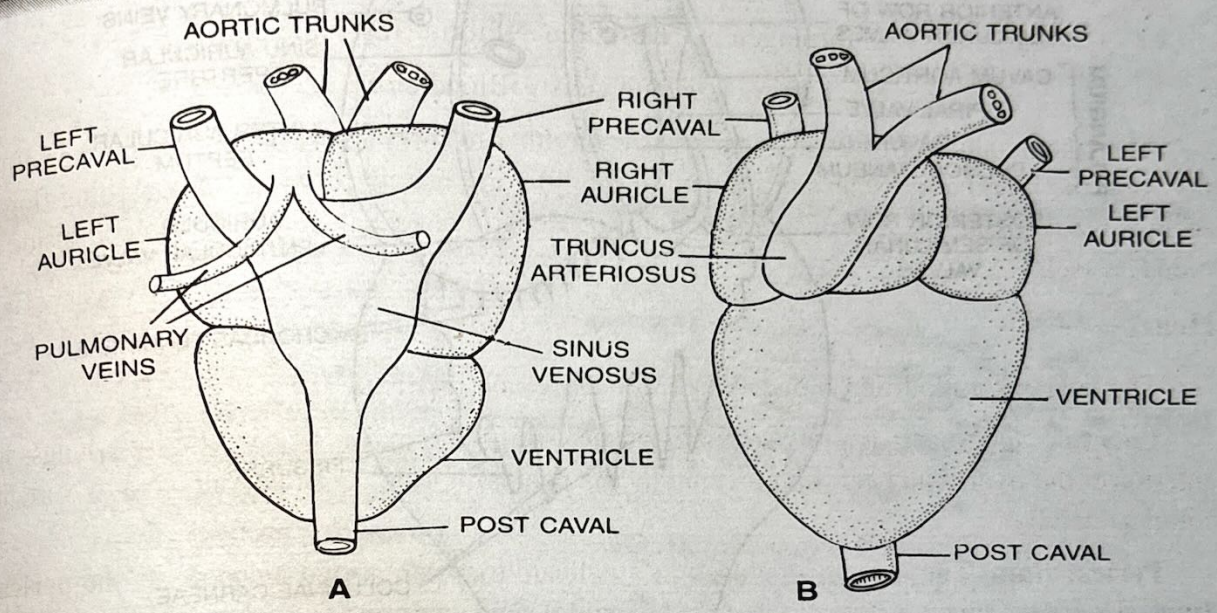


Fig. 7A.69. Heart of frog : External structure. A, Dorsal view. B, Ventral view.

The cavity of the synangium is further divided into a dorsal and ventral chamber by a horizontal partition called **primary septum** or **septum principle**. The dorsal chamber communicates with cavum pulmocutaneum while ventral chamber with the cavum aorticum.

The synangium bifurcates into two branches as **aortic trunks**. Each aortic trunk divides into three arches, the **pulmocutaneous, systemic** and **carotid arches**. A small opening of the pulmocutaneous arch is present in the cavum pulmocutaneum just behind the anterior row of semilunar valves. This opening is guarded by a small valve.

Thus, the cavum pulmocutaneum leads into the dorsal chamber of synangium and then dorsal chamber opens into pulmocutaneous arch. While the cavum aorticum leads into the ventral chamber of synangium and then the ventral chamber opens into both systemic and carotid arches.

In addition to the above mentioned structures, there is present one sinus venosus.

Histologically, the wall of the heart consists of three layers : outer smooth **visceral pericardium**, middle muscular **myocardium** and inner **endothelium** comprising epithelial cells.

Working of Heart. Heart of frog is **myogenic** (heart beat originates from a muscle however it is regulated by the nerves). Wave of contraction originates from the sinus venosus and spreads over the wall of the sinus venosus and both the auricles. It compels the heart to beat. The

contraction of the heart is termed as **systole** while its expansion is called **diastole** and both constitute one heart beat.

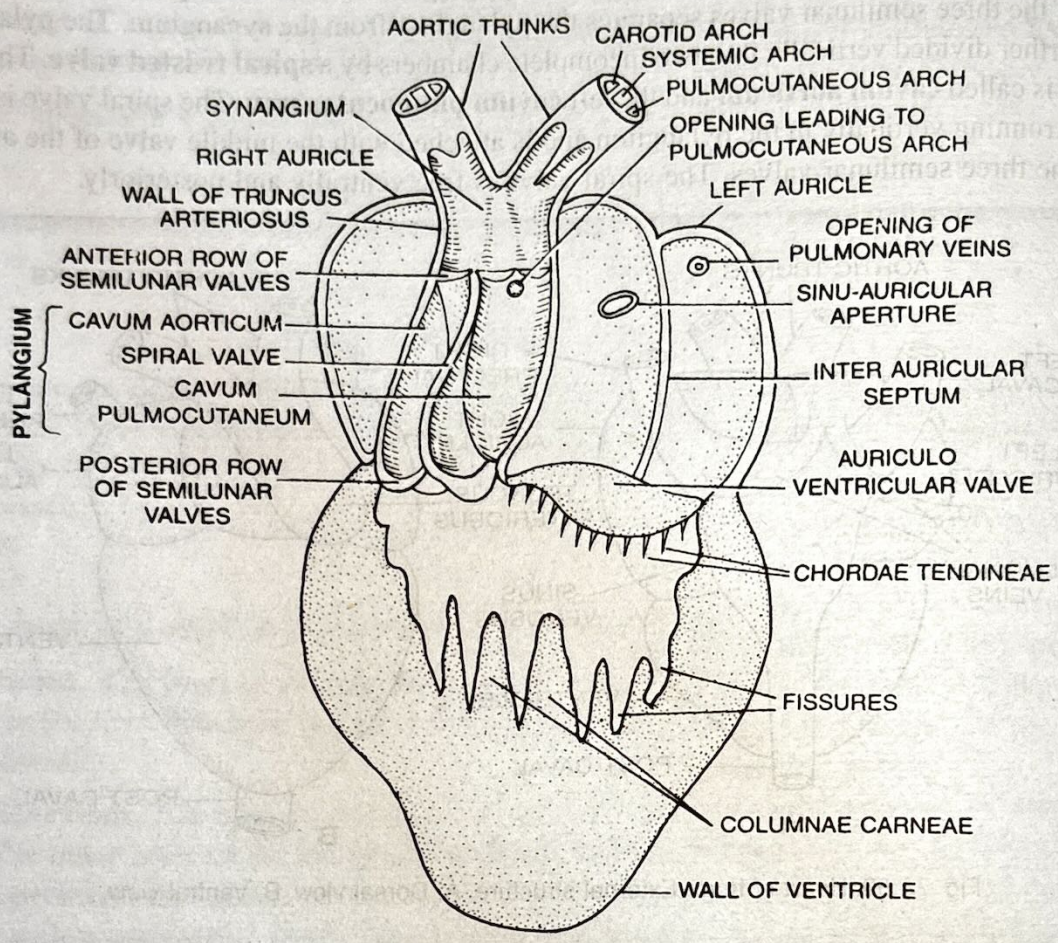


Fig. 7A.70. Internal structure of heart of frog (ventral view).

The sinus venosus contracts, whose contraction drives the **mixed blood** from the sinus venosus to the right auricle. At the same time, the left auricle receives **oxygenated blood** through the opening of the pulmonary veins from the lungs. When the two auricles are full of blood, they contract simultaneously. The backward flow of the blood into the sinus venosus is prevented by the sinu-auricular valves. The blood cannot go back into pulmonary veins as the openings of the pulmonary veins are small and oblique which are closed automatically by the contraction of the left auricle. Thus, the blood from both the auricles is forced into the single ventricle through auriculo-ventricular aperture. The auriculoventricular node is stimulated by the auricular contraction and passes a fresh wave of the contraction over the wall of the ventricle.

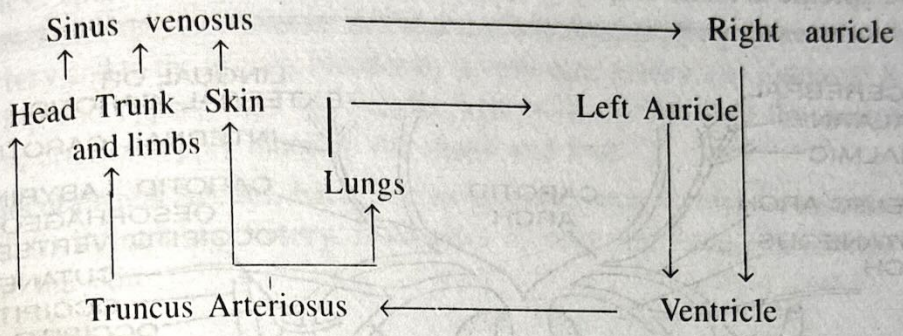
Thus both oxygenated and deoxygenated blood are mixed in the ventricle. Now the ventricle contracts and the backward flow of blood into auricles is prevented by the auriculoventricular valve. The mixed blood of the ventricle enters the truncus arteriosus. From the truncus arteriosus mixed blood goes to three arches (carotid, systemic and pulmocutaneous) and ultimately reaches all the parts of the body.

Control of Heart Beat. The contraction of heart (systole) and the relaxation of heart (diastole) constitute the heart beat. The rate of heart beat is controlled by the medulla oblongata of

the brain and by certain hormones such as **adrenalin** and **thyroxine**. Increase in carbon dioxide and temperature also affects the sinus venosus and thereby it increases the rate of heart beat.

In frog cardiac cycle is completed in about 0.9 seconds. This means that frog's heart beats about 64 times per minute.

Blood circulation. It can be represented by the following graphical sketch.



Blood Vessels

Arteries, arterioles, veins, venules and blood capillaries are called blood vessels. **Arteries** carry blood from the heart to different body parts. **Veins** bring blood from different body parts to the heart. Arteries divide to form **arterioles**. The arterioles divide to form **blood capillaries** which unite to form **venules**. The venules join to form veins. The veins have valves to prevent backward flow of blood. Exchange of nutrients, hormones, gases, etc. takes place between blood capillaries and body cells.

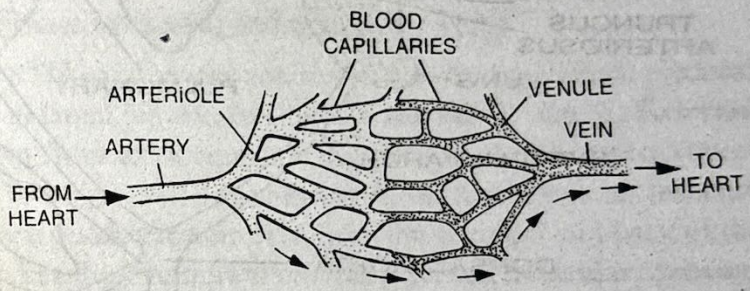


Fig. 7A.71. Diagram showing the end of an artery and beginning of a vein.

Arterial System

The truncus arteriosus divides into right and left aortic trunks. Each aortic trunk divides into three arches— **carotid arch, systemic arch** and **pulmocutaneous arch**.

A. **Carotid Arches.** Each carotid arch divides into two arteries : lingual (= external carotid) and internal carotid. (i) **Lingual (= External Carotid) Artery**. It carries blood to the tongue and hyoid apparatus. (ii) **Internal Carotid Artery.** It immediately swells up to form the **carotid labyrinth**. The latter is probably a sense organ to note changes in blood pressure. Internal carotid artery divides into 3 branches : **ophthalmic, cerebral** and **palatine arteries** which supply blood to the eye, brain and roof of the bucco–pharyngeal cavity respectively.

B. **Systemic Arches.** Two systemic arches join to form a single vessel, the **dorsal aorta**.

Each systemic arch, before it joins its fellow from the otherside, gives off two arteries : oesophageo-occipitovertebral and subclavian.

(i) **Oesophageo–occipitovertebral Artery.** It bifurcates into an oesophageal and occipitovertebral arteries. (a) **Oesophageal Artery.** It carries blood to the oesophagus. (b) **Occipitovertebral Artery.** It divides into **occipital artery** and **vertebral artery** which send blood to the back of the head and the anterior part of the vertebral column (back bone) respectively.

(ii) **Subclavian Artery.** It supplies blood to the shoulder and the forelimb.

The **dorsal aorta** runs poteriorly and gives off the following arteries :

(i) **Coeliaco–mesenteric Artery.** It is a stout artery which divides into two branches : coeliac and anterior mesenteric arteries. (a) **Coeliac Artery.** It gives off a **hepatic artery** to the liver and a **gastric artery** to the stomach. (b) **Anterior Mesenteric Artery.** It supplies blood to the duodenum, pancreas, ileum and spleen through small branches called the **duodenal, pancreatic, intestinal** and **splenic arteries** respectively.

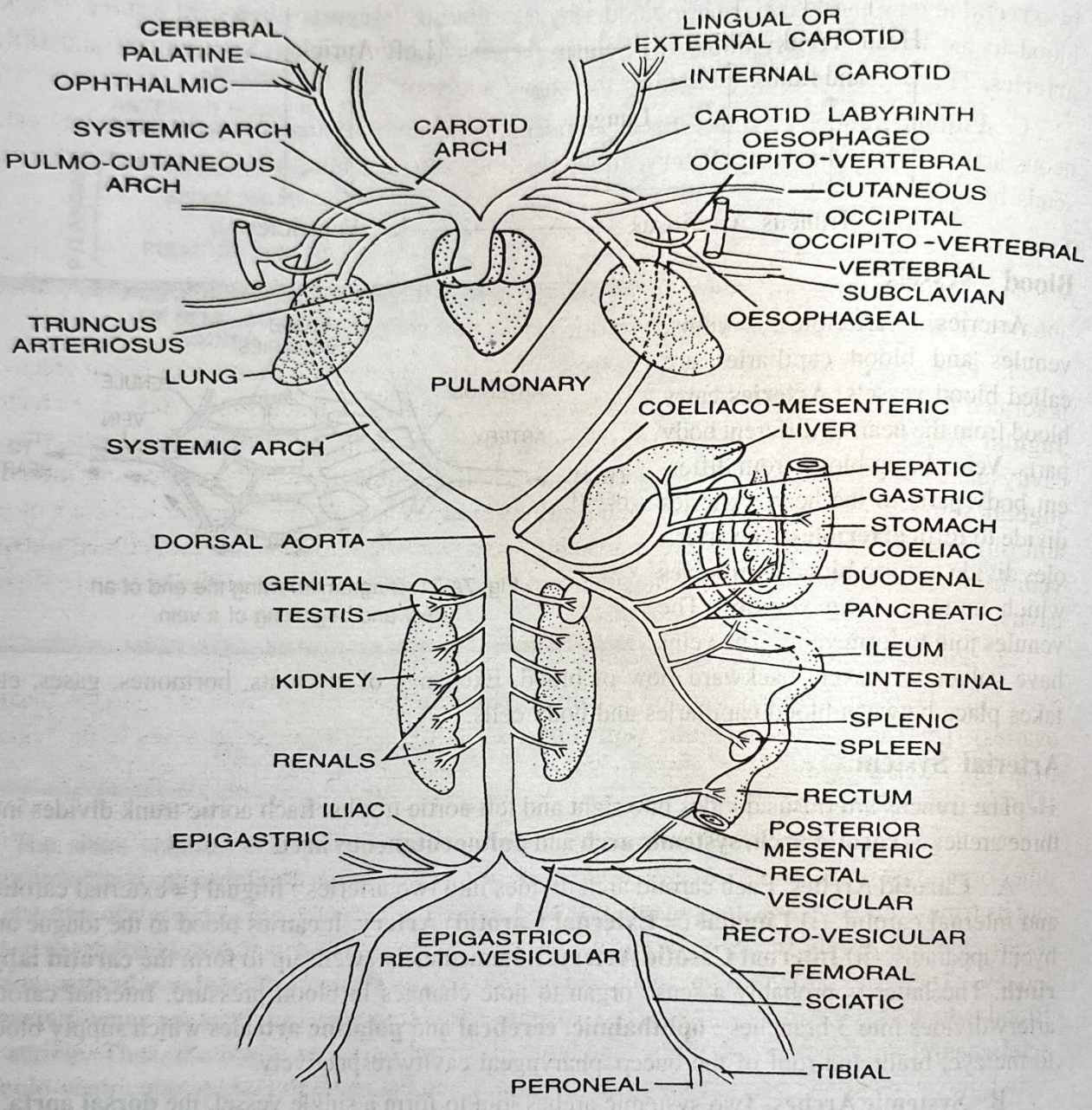


Fig. 7A.72. Arterial system of Frog.

(ii) **Genital Arteries.** These are a pair of arteries. They carry blood to the gonads (testes, ovaries). They are called the **spermatic arteries** in the male frog and **ovarian arteries** in the female frog.

(iii) **Renal Arteries.** These are 4 or 5 pairs of arteries which supply blood to the kidneys.

(iv) **Lumbar Arteries.** These are several small vessels (not shown in the figure) that leave the dorsal aorta dorsally in the region of the renal arteries. They supply blood to the dorsal body wall.

(v) **Posterior Mesenteric Artery.** It carries blood to the rectum. *Sometimes, it arises from the anterior mesenteric artery.*

(vi) **Iliac Arteries.** These are a pair of arteries formed by bifurcation of the dorsal aorta. Each iliac artery gives off an epigastricorectovesicular artery and passes into the leg of its side. Here it divides into the femoral and sciatic arteries. (a) **Epigastricorectovesicular Artery.** It divides into two arteries : **epigastric** and **rectovesicular**. The epigastric artery sends blood to the ventral abdominal muscles. The rectovesicular artery supplies blood to the posterior part of the rectum by a **rectal artery** and to the urinary bladder by a **vesicular artery**. (b) **Femoral Artery.** It sends blood to the hip and upper thigh. (c) **Sciatic Artery.** It divides into the **peroneal** and **tibial arteries**. These arteries supply blood to the shank and foot.

C. **Pulmocutaneous Arches.** Each pulmocutaneous arch divides into pulmonary and cutaneous arteries. (i) **Pulmonary Artery.** It supplies blood to the lung. (ii) **Cutaneous Artery.** It sends blood to the skin.

Venous System

The venous system of frog may be studied under the following headings : precavals (= anterior venaecavae), post caval (= posterior venacava) and pulmonary veins.

1. **Precavals.** Two pre cavals collect blood from the anterior part of the body. Each precaval is formed by the union of three veins : external jugular, innominate and subclavian. (i) **External Jugular Vein.** It receives a **lingual vein** from the tongue and the floor of the buccopharyngeal cavity and a **mandibular vein** from the lower jaw. (ii) **Innominate Vein.** It receives an **internal jugular vein** from the brain, eye, etc. and a **subscapular vein** from the shoulder and back of the arm. (iii) **Subclavian Vein.** It receives a **brachial vein** from the fore limb and **musculocutaneous vein** from the skin and muscles of the abdomen and mucous membrane of the buccopharyngeal cavity.

2. **Postcaval.** It is a long, thick vein which receives the following veins :

(i) **Genital Veins.** These are a pair of veins bringing blood from the gonads (testes, ovaries). They are called **spermatic veins** in the male frog and the **ovarian veins** in the female frog. (ii) **Renal Veins.** These are 4 to 6 pairs of veins carrying blood from the kidneys. (iii) **Hepatic Veins.** These are a pair of veins bringing blood from the liver. (iv) **Renal Portal System.** When a vein carries blood from some part of the body and forms a network of capillaries in some other organ instead of going directly to the heart, the vein is called **portal vein**. The portal vein and its tributaries constitute the **portal system**. A portal system is named after the organ to which it carries blood. **Renal portal system** carries blood from the posterior region of the body to the kidneys. The renal portal system includes the following veins. (a) **Femoral** and **Sciatic Veins.** Blood from each hindlimb is brought by two veins : the **femoral vein** from the outer side and the **sciatic vein** from the inner side of the hind limb. (b) **Renal Portal** and **Pelvic Veins**. Each femoral vein bifurcates into the **pelvic vein** on the inner side and the **renal portal vein** on the outer side.

The renal portal vein receives the sciatic vein and then proceeds forward towards the kidney of its side. The renal portal vein is joined by a **dorso-lumbar vein** from the dorsolateral parts of the body wall and **oviducal vein** from the oviduct in the female. It then enters the kidney, where it breaks up into capillaries.

Two pelvic veins join together to form the **anterior abdominal vein** which runs forwards along the abdominal wall. On its way forwards, the anterior abdominal vein receives a **vesicular vein** from the urinary bladder and several pairs of small veins from muscles of abdominal wall. Anteriorly reaching close to the liver the anterior abdominal vein joins with a small branch of hepatic portal vein and enters the liver. Inside the liver it breaks up into capillaries.

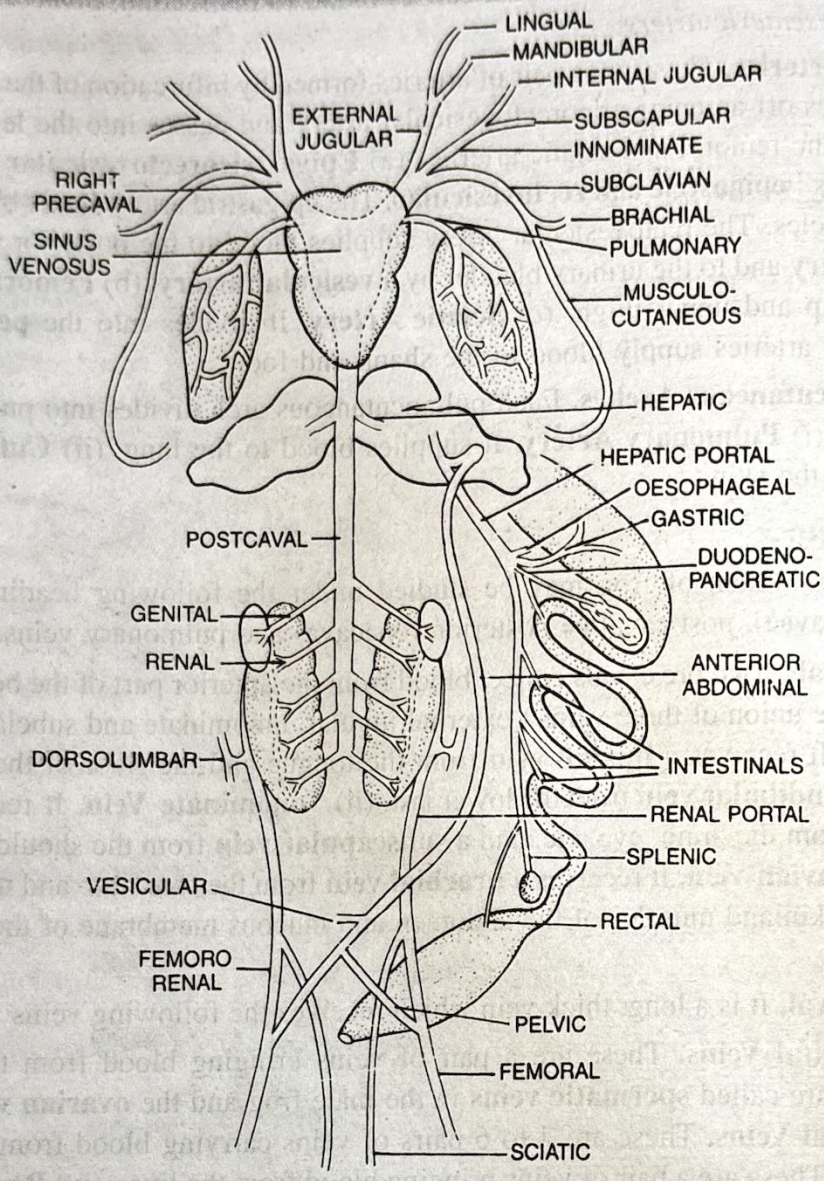


Fig. 7A.73. Venous system of frog.

Significance of Renal Portal System. The renal portal system collects the blood from the hind parts on the body from which the urea and uric acid present in the blood are first got filtered in the kidneys before the blood goes into postcaval and then to the heart. Thus, the blood going to the heart contains comparatively less impurities after passing through the renal portal system.

(v) **Hepatic Portal System**. Hepatic portal system carries blood from the alimentary canal and its associated glands to the liver. It consists of a large **hepatic portal vein** that receives a number of tributaries namely **oesophageal, gastric, duodenopancreatic, intestinals, splenic** and **rectal** from the oesophagus stomach, duodenum and pancreas, small intestine, spleen and rectum respectively.

Significance of hepatic portal system. The hepatic portal system has following significance.

(i) The blood which comes from the alimentary canal contains digested food like glucose and amino acids. The excess of glucose is converted into glycogen which is stored in the liver for later use. When an individual feels deficiency of food, the glycogen is converted into glucose and is transferred to the blood stream via hepatic veins. (ii) Harmful nitrogenous waste like am-

monia is converted into urea which is later removed by kidneys. Thus the blood is detoxified (purified) of harmful nitrogenous waste. (iii) Liver produces blood proteins which are put into blood circulation.

Differences between Arteries and Veins

Arteries	*Veins*
1. Arteries carry blood from heart to the different organs of the body.	1. Veins collect blood from different organs of the body and pour it into the heart.
2. They are usually deep seated.	2. They are superficially situated.
3. The walls of the arteries are thick, muscular and non-contractile.	3. The walls of the veins are thin, non-muscular and contractile.
4. Arteries are not collapsible as they have thick walls.	4. Veins are collapsible because they have thin walls.
5. The arteries have no valves.	5. The veins contain valves which prevent the backward flow of the blood.
6. They have smaller lumen.	6. The lumen of the veins is larger.
7. In arteries, blood flows with jerks.	7. In veins, blood flows smoothly.
8. The flow of the blood is fast as the blood in them is under great pressure.	8. The flow of the blood in veins is not so fast because the blood in veins is under decreased pressure.
9. They become empty after the death of the animal.	9. They contain blood even after the death of the animal.
10. Except the pulmocutaneous arteries, all the arteries contain oxygenated blood.	10. Except pulmonary veins all the veins contain deoxygenated blood.

3. **Pulmonary Veins.** The oxygenated blood from each lung is carried by a **pulmonary vein.** The two pulmonary veins join to form the **common pulmonary vein**. The latter opens into the left auricle of the heart.

Lymphatic System

It is the second part of the circulatory system, through which a mobile connective tissue, the lymph, is circulated. Lymphatic system comprises (a) Lymph, (b) Lymph capillaries, (c) Lymph sinuses and (d) Lymph hearts.

(a) **Lymph**. Lymph is a **mobile connective tissue** like blood which is composed of two parts: (1) **Plasma**. It is similar to blood plasma but has got less number of proteins. Mainly globulin proteins are present. Other components of the lymph plasma are very much like that of blood plasma, *i.e.*, organic, inorganic substances. (2) **Corpuscles**. *Red blood corpuscles (Erythrocytes) are completely absent*. Leucocytes are numerous which are mainly lymphocytes. Thrombocytes (spindle shaped cells) are few in number due to which the clotting of the lymph is very slow.

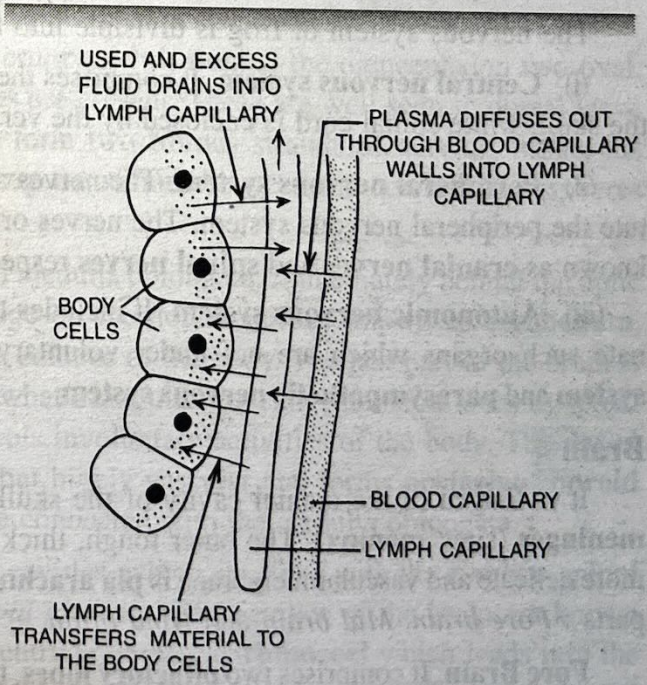

USED AND EXCESS FLUID DRAINS INTO LYMPH CAPILLARY
PLASMA DIFFUSES OUT THROUGH BLOOD CAPILLARY WALLS INTO LYMPH CAPILLARY
BODY CELLS
BLOOD CAPILLARY
LYMPH CAPILLARY
LYMPH CAPILLARY TRANSFERS MATERIAL TO THE BODY CELLS

Fig. 7A.74. Relationship between the blood capillaries; lymph capillaries and body cells.

Functions of Lymph. (a) Lymph acts as middle man transporting oxygen, food material, hormones, etc., to the body cells and bringing carbon dioxide, waste products, etc., from the body cells and then finally pouring the same into the venous system. (1) Body cells are also kept moist by the lymph. (2) Lymphocytes present in the lymph fight against the infection. (3) It transports the fatty acids and glycerol from the intestine. (4) Lymphocytes present in the lymph help in assisting the repair of the tissues. (5) It maintains the volume of the blood.

(b) **Lymph Capillaries**. Lymph capillaries lie very close to the blood capillaries but differ from them, as they end blindly in contact with the body cells or the tissue spaces. The lymph always flows from the tissues towards the lymph hearts. Their walls are extremely thin and permeable to colloids, crystalloids and water. They do not have a constant shape. The lymph capillaries of the intestine transport the digested fat, which does not pass through blood stream directly. Because these capillaries contain fat, they appear milky white, hence are termed as **lacteals** (*lactos* = milk).

(c) **Lymph Sinuses**. In the frogs, lymph vessels are not found. Instead of these vessels, there are present thin walled spaces or **lymph sinuses** around the tissues and between the organs. The important lymph sinuses are **subcutaneous sinuses** and **subvertebral sinus**.

(d) **Lymph Hearts**. There are present two pairs of thin walled, muscular lymph hearts, one pair is located behind the transverse processes of third vertebra and the other is situated in the region of urostyle.

The flow of lymph is from the lymph capillaries →lymph sinus →lymph hearts →veins.

Spleen

It is a dark, red oval structure lying near the anterior end of the rectum. It produces RBCs and WBCs in adult too. It stores blood hence it is called "blood bank".

Nervous System

The nervous system of frog is divisible into three parts.

(i) **Central nervous system**. It comprises the **brain** and **spinal cord**. The brain is lodged in the skull, while spinal cord is enclosed by the vertebral column.

(ii) **Peripheral nervous system**. The nerves arising from the central nervous system constitute the peripheral nervous system. The nerves originate from the brain and spinal cord and are known as **cranial nerves** and **spinal nerves** respectively.

(iii) **Autonomic nervous system**. It includes the nerves and ganglia that control and coordinate such organs which are not under voluntary control. It comprises **sympathetic nervous system** and **parasympathetic nervous system**.

Brain

It is lodged in the cranial cavity of the skull. The brain is covered by two membranes or **meninges** (sing. **meninx**). The outer tough, thick membrane is **duramater**, and the inner thin, more delicate and vascular membrane is **pia arachnoid membrane**. The brain is divisible into three parts : *Fore brain, Mid brain* and *Hind brain.*

Fore Brain. It comprises two **olfactory lobes**, two **cerebral hemispheres** and a **diencephalon**. Dorsal surface of the diencephalon has **anterior choroid plexus** to supply nourishment to the anterior parts of the brain. From the dorsal side of the diencephalon also arises a short cylindrical **pineal stalk,** which carries knob like **pineal body**. The pineal body is an endocrine gland. The position of pineal body is indicated externally by the **brow spot**. A pair of thick optic nerves cross and form **optic chiasma** on the ventral side of the diencephalon. Just behind the optic chiasma, a

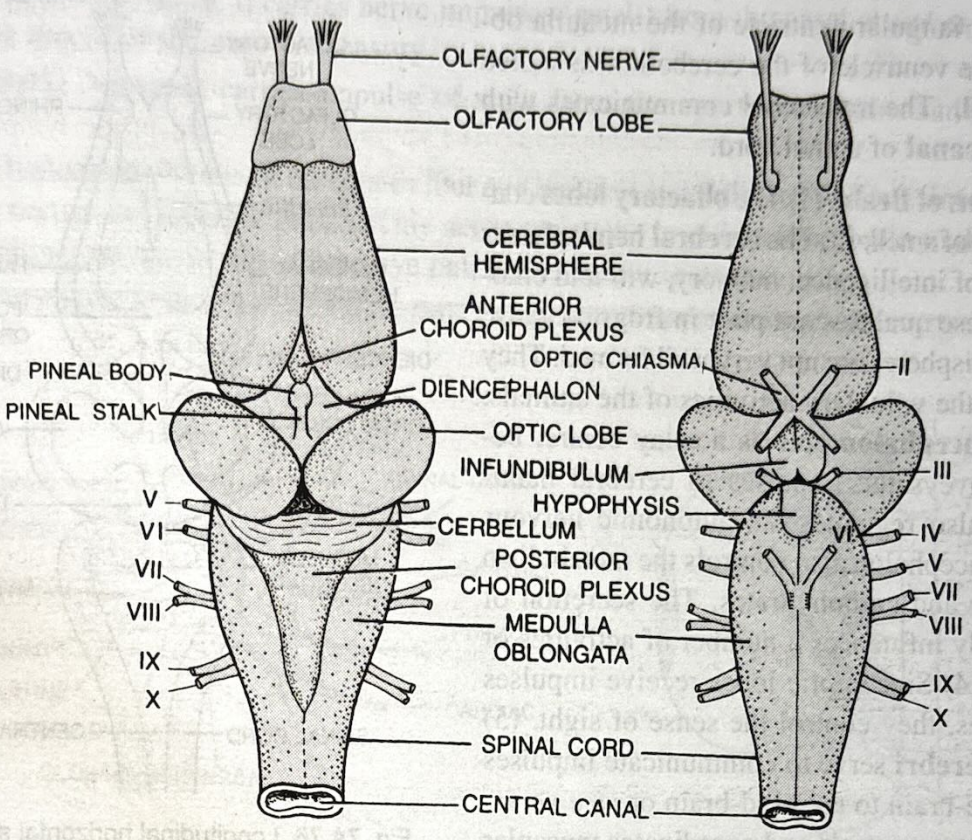


Fig. 7A.75. Brain of frog. A. Dorsal view, B. Ventral view. I to X cranial nerves.

small outgrowth is formed by the diencephalon, which is termed as **infundibulum**. Further, behind the infundibulum and attached to it a flattened ovoid sac, the **hypophysis** (**pituitary gland**) is present. It is an important endocrine gland (ductless gland). It produces very important hormones.

Mid Brain. It consists of optic lobes and crura cerebri. Behind the diencephalon two oval, large slightly pressed to the outside, **optic lobes** are present. These are well seen in dorsal view. On the ventral side, the brain is thickened to form two fibrous strands of nervous tissue, the **crura cerebri** (sing. crus-cerebrum), which carry the stimuli between the cerebral hemispheres and medulla oblongata.

Hind Brain. It comprises cerebellum and medulla oblongata. Immediately behind the optic lobes, there is present a sort of transverse ridge on the dorsal surface known as **cerebellum**, which is poorly developed in frog. It maintains balance of the body. The last part of the brain is **medulla oblongata**, which is stout, and somewhat triangular in shape and continues as spinal cord posteriorly. The medulla oblongata controls involuntary activities of the body. The dorsal side of the medulla oblongata is non-nervous but highly vascular and forms **posterior choroid plexus**. The cranial nerves from 5th to 10th are connected with the medulla oblongata.

Ventricles. The brain is hollow containing cavities, which are filled with the **cerebro-spinal fluid** *secreted by anterior and posterior-choroid plexuses*. The cavities of the brain are known as ventricles. Each olfactory lobe encloses a ventricle termed as **rhinocoel** which leads into the ventricles of the cerebral hemisphere, the **lateral ventricles** or **paracoels** or **first** and **second ventricles**. Two lateral ventricles open into the ventricles of the diencephalon, the **diocoel** or **third ventricle** through an aperture, the ***foramen of Monro**. Each optic lobe contains a cavity which is called **optocoel**. The two optocoels open into a narrow tubular cavity, the **iter** which

* Foramen named after its discoverer A. Monro, Scottish Anatomist.

connects the diocoel with the **myelocoel** or **fourth venticle** (a triangular ventricle of the medulla oblongata). The ventricle of the cerebellum is called the **metacoel.** The myelocoel communicates with the **central canal** of spinal cord.

Functions of Brain. (1) The **olfactory lobes** control the sense of smell. (2) The **cerebral hemispheres** are the seat of intelligence, memory, will and emotions, but these qualities are poor in frogs, because cerebral hemispheres are not very well formed. They also control the voluntary activities of the animals. (3) The **diencephalon** acts as a relay centre, because it conveys the impulses to cerebral hemispheres. It also regulates the autonomic nervous system. Diencephalon also controls the metabolism of fat, water and carbohydrates. The secretion of pituitary body influences a number of activities of the animal. (4) Since optic lobes receive impulses from the eyes, they control the sense of sight. (5) The **crura cerebri** serve to communicate impulses from the fore-brain to the hind-brain or *vice versa.* (6) **Cerebellum** controls and coordinates muscular movements, thus it mainly controls equilibrium and locomotion of the animal. It is a reduced structure in frog. (7) **Medulla oblongata** controls and regulates the various involuntary activities, such as heart beat, respiration, nutrition, sound production and metabolism in general.

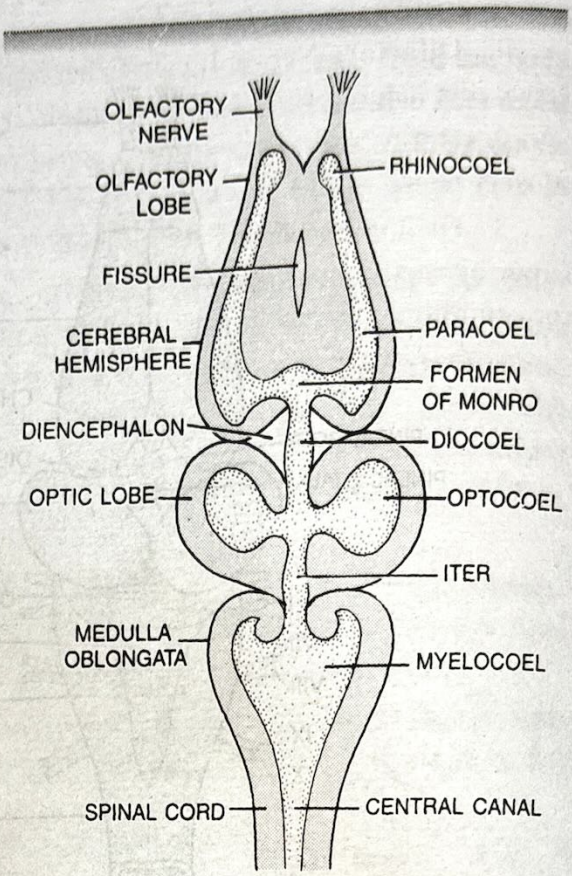


Fig. 7A.76. Longitudinal horizontal section of Brain of frog showing ventricles.

Spinal Cord (= Myelon)

It lies in the neural canal of vertebral column and extends from the medulla oblongata of the brain to almost the end of back-bone. The spinal cord is surrounded by the same two protective membranes; the meninges, as in the brain viz., a thick outer **duramater** and a thin inner vascular **pia-arachnoid membrane.**

In frog, it is short, somewhat flattened structure which widens anteriorly and tapers towards the posterior end into the urostyle, where it is called **filum terminale**. The spinal cord shows two swollen parts, one near the arms and the other near the hind limbs known as **brachial** and **sciatic enlargements** respectively. These enlargements supply large nerves to the arms and legs.

All along its length, spinal cord has two median longitudinal grooves, the **dorsal fissure** on the dorsal side and **ventral fissure** on the ventral side while the latter is more grooved.

Spinal cord serves two main **functions** :

(i) The stimuli are passed from and to the brain through spinal cord.

(ii) It is the centre of spinal reflex action.

Cranial Nerves

The nerves which connect the brain and leave the brain box (**cranium**) are known as **cranial nerves.** The number of cranial nerves is definite in a particular group of animals. In frog, thenumber is **ten pairs**. The serial number of a nerve is also definite.

1. **Olfactory Nerve**. It carries nerve impulses (smell) from the nasal chamber to the brain, hence, the nature of the nerve is sensory.

2. **Optic Nerve.** It carries impulse of sight from the eye to the brain, and its nature is sensory.

3. **Oculomotor Nerve.** It innervates four eye muscles viz., **inferior oblique**, **internal rectus**, **superior rectus** and **inferior rectus**. This nerve caries the impulses from brain to these muscles for controlling the movements of the eye ball and is motor in nature.

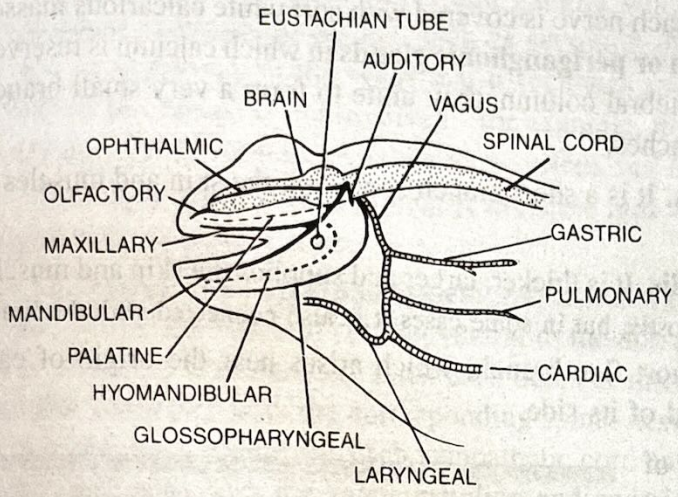


Fig. 7A.77. Showing I, V, VII, VIII, IX and X cranial nerves of frog.

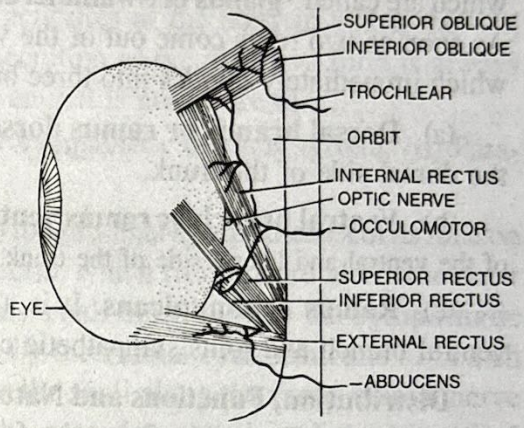


Fig. 7A.78 Nerve supply of the eye ball of frog.

4. **Trochlear (Pathetic) Nerve**. It is distributed to one eye muscle, the **superior oblique**. This nerve helps in controlling the movement of eye ball and its nature is motor.

5. **Trigeminal Nerve.** It divides into three branches. (i) **Ophthalmic Nerve.** It innervates the skin receptors of the snout. Thus, it conveys impulses from the skin of this area to the brain and, hence sensory in nature. (ii) **Maxillary Nerve.** It supplies the receptors of the skin, upper jaw, upper lip, lower eye-lid and carries the impulses from these areas to brain and hence is sensory in nature. (iii) **Mandibular Nerve.** It innervates the skin and muscles of the lower jaw and tongue. It is mixed branch. It carries sense of touch from lower jaw to the brain. It also controls the movement of lower jaw.

The total nature of trigeminal nerve is mixed.

6. **Abducens Nerve**. It supplies the remaining eye muscle, the **external rectus** and controls the movement of the eye ball and is motor in nature.

7. **Facial Nerve**. It divides into two branches. (i) **Palatine Nerve**. It supplies the roof of the buccal cavity (palate) and carries the sense of taste to the brain. So, it is sensory in nature. (ii) **Hyomandibular Nerve.** It innervates the muscles of hyoid apparatus, muscles and skin of lower jaw. It controls the activities of these organs and also conveys the sense of touch from skin of lower jaw. Its nature is mixed. Thus, total nature of the facial nerve is mixed.

8. **Auditory Nerve.** It supplies the ear and carries impulses from the ear to the brain, thus helps in hearing and balancing the organs. The nature of this nerve is sensory.

9. **Glossopharyngeal Nerve**. It supplies the taste buds of tongue and muscles of the pharynx. Some fibres carry impulses from tongue, while the other fibres are responsible for pharynx movement as they are concerned with swallowing reflex. Thus, both sensory and motor nerve fibres are present in this nerve. The nature of this nerve is mixed.

10. **Vagus Nerve.** It is to be noted that it is the only cranial nerve, which enters the body cavity after emerging from the brain box (cranium). It divides into the following branches. (i) **Laryngeal Nerve.** It supplies the laryngeotrachial chamber. (ii) **Cardiac Nerve.** It innervates the heart. (iii) **Gastric Nerve.** It supplies the stomach. (iv) **Pulmonary Nerve.** It innervates the lungs. Vagus is mixed in nature because it carries both motor and sensory fibres.

Spinal Nerves

These nerves arise from the spinal cord and are normally nine pairs, sometimes 10th unpaired nerve is also seen. Rarely 10 pairs of spinal nerves are found. As soon as the spinal nerve comes out of the vertebral column, the origin of each nerve is covered with soft white calcarious masses, which are called ***glands of Swammerdam or periganglionic glands** in which calcium is reserved. As soon as two roots come out of the vertebral column, they unite to form a very small branch, which immediately divides into three branches.

(a) **Dorsal branch or ramus dorsals.** It is a short branch supplying the skin and muscles of the dorsal side of the trunk.

(b) **Ventral branch or ramus ventralis**. It is thicker, larger and supplies the skin and muscles of the ventral and lateral side of the trunk mostly, but in some cases it is also connected with the limbs.

(c) **Ramus communicans**. It is a short fine branch, which arises near the origin of each ventral branch and joins sympathetic cord of its side.

Distribution, Functions and Nature of Spinal Nerves. Except the first pair of spinal nerve, all are distributed to the skin and muscles of the respective parts of the body. They carry impulses from the skin receptors to the spinal cord and from the spinal cord to the muscles. Thus, their nature is **mixed.**

1st. The first spinal nerve is also known as **hypoglossal Nerve**. It supplies muscles of the tongue, floor of the buccal cavity and some muscles of the shoulder and back. It also takes part in the formation of brachial plexus. It is a motor branch.

2nd and 3rd. The hypoglossal nerve, the second and the third spinal nerves form the **brachial plexus.** From the brachial plexus, the second nerve continues as a **brachial nerve** to the skin and muscles of fore-limb.

4th, 5th and 6th. The 4th, 5th and 6th spinal nerves supply the skin and muscles of the body wall of the belly region.

7th, 8th and 9th. The 7th, 8th and 9th spinal nerves form the **sciatic plexus**, which gives off branches to the skin and muscles of the abdomen and hind-limbs. This plexus also supplies some branches to the large intestine, genital ducts and urinary bladder.

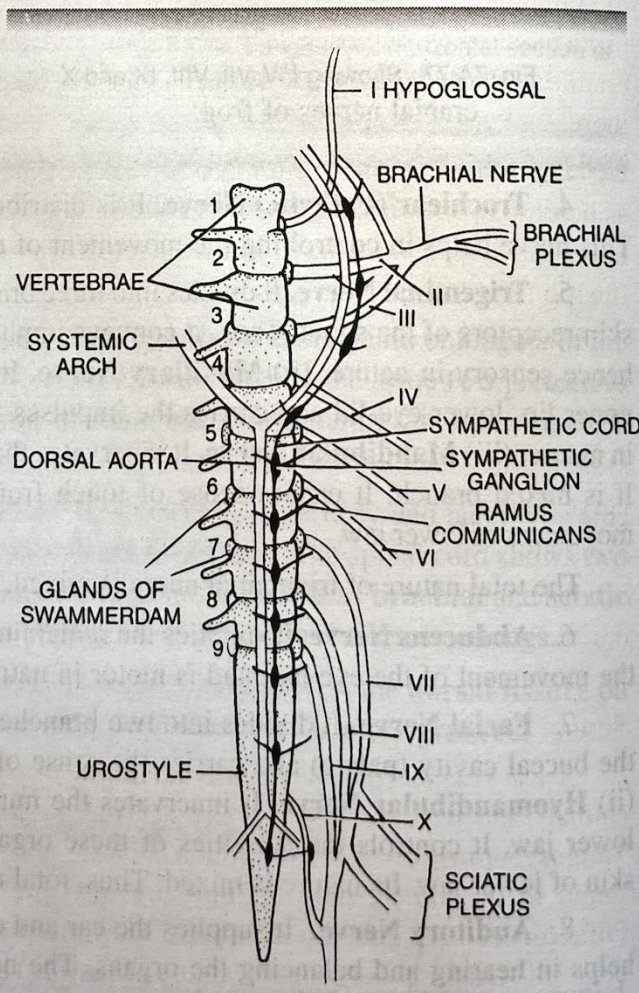


Fig. 7A.79. Spinal nerves and sympathetic nervous system of frog. Structures are shown on one side only.

* Also named as Swammerdam's glands [J.Swammerdam, Dutch naturalist]

10th. The tenth nerve is also known as **coccygeal nerve,** which is not commonly found in *Rana*. Whenever this nerve is present, it emerges from the urostyle through an aperture and joins the sciatic plexus. The fine branches of 10th nerve supply the urinary bladder and cloaca.

There is a noteworthy point that the roots of seventh to tenth nerves first run inside the neural canal of the vertebral column for some distance to form a horse-tail shaped structure, the **cauda equina**. Later on these nerves come out of the neural canal.

Autonomic Nervous System

It is a system of nerve fibres and ganglia which control and coordinate the involuntary activities of the visceral organs, such as secretion of digestive fluid, action of heart, etc. This system is autonomic in the sense that it regulates such activities of the body in which the will power of the animal is not involved, for example, the secretion of the digestive fluid is always under the control of autonomic nervous system, but the animal is not aware of it.

The autonomic nervous system is divisible into –*(i)* Sympathetic nervous system. *(ii)* Parasympathetic nervous system.

(i) **Sympathetic Nervous System**. It consists of two longitudinal **sympathetic cords**, one on either side of the vertebral column ventral to the dorsal aorta, which run forward along the outer sides of the systemic arches. Each cord bears at intervals small black nine to ten **sympathetic ganglia** connected with the corresponding spinal nerves by the **ramus communicans** (a branch of spinal nerve). Anteriorly, each sympathetic cord enters the skull along the vagus cranial nerve (10th) and joins with the vagus ganglion and ends in the gasserian ganglion of the trigeminal cranial nerve (5th). Posteriorly each sympathetic cord joins the 9th spinal nerve and later on ends there.

The nerves arising from the sympathetic ganglia supply the respective visceral organs, such as heart, liver, stomach, intestine, kidneys, gonads, blood vessels, urinary bladder, etc. On stimulation the sympathetic nerve fibres secrete a chemical **sympathin**, which stimulates the organs to function. Example : It increases heart beat.

(ii) **Parasympathetic Nervous System.** There is no such cord or ganglia as found in the sympathetic nervous system. It consists of very small parasympathetic ganglia situated in the walls of visceral organs (viscera) and nerve fibres. These are connected with the central nervous system after travelling in some **cranial** and **spinal nerves**. On stimulation, the parasympathetic nerve fibres secrete a chemical called **acetylecholine**, whose function is just opposite to that of sympathin. Example : It slows heart beat.

The function of sympathetic and parasympathetic nervous system is **antagonistic** to each other. Autonomic nervous system is ultimately controlled by diencephalon (hypothalamus) of the brain.

Sense Organs

Sense organs receive stimuli (changes in the environment) from outside or inside of the animals and pass impulses to the nervous system. Frog has five types of sense organs : (i) **Tangoreceptors (organs of touch)**. These are nerve endings and touch corpuscles which are found in the skin. Nerve endings are also present in the viscera (soft internal organs). (ii) **Olfactoreceptors (organs of smell).** They are present in the nasal epithelium of the nasal chambers. (iii) **Gustatoreceptors (Organs of taste).** These are found as taste buds which are present in the epithelium of the tongue and the buccopharyngeal cavity. (iv) **Photoreceptors (organs of sight)**— eyes. (v) **Statoacoustic receptors** (Hearing and balancing organs)–Ears.

Out of these eyes and ears are well organised. They are described below.

Structure of Eye of Frog

Eye lids and gland. Each eye is provided with upper and lower eye lids which are actually simple folds of skin. The **upper eye lid** is thick and very slightly *movable*. The **lower eye lid** is vestigial and *immovable*. The **nictitating membrane** is movable, semitransparent and can be drawn over the eye when animal is inside water where it prevents aquatic infection and also enables the frog to see under water. This membrane is retracted when the frog is on land. A **harderian gland** is present below the lower eye lid whose secretion lubricates the eye ball and nictitating membrane.

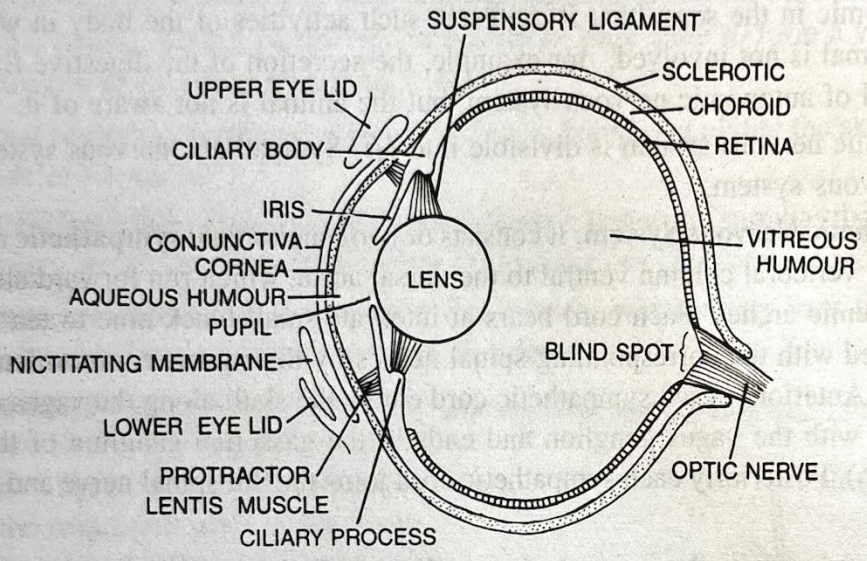


Fig. 7A.80. V. S. Eye of Frog.

Muscles attached to the Eye Ball Six other muscles are attached to the eye which bring about the movements of the eye ball. The four muscles are recti, namely, **superior rectus, inferior rectus, internal rectus, external rectus** and two oblique muscles : **superior oblique** and **inferior oblique**. The superior oblique is supplied by fourth cranial nerve, inferior oblique, internal rectus, superior rectus and inferior rectus are innervated by 3rd cranial nerve while external rectus gets sixth cranial nerve.

Layers of eye ball. The wall of the eye ball mainly consists of three layers : Outer fibrous coat, middle vascular coat and inner nervous coat.

(i) **Outer Fibrous Coat.** It is the outermost layer of eye ball which is fibrous in nature. Two third part of this layer is opaque and lies inside the eye orbit and is known as **sclerotic**. The muscles controlling the movement of eye ball are attached on it. The remaining one-third of the outer layer is transparent and bulges out to form the **cornea**. The cornea is lined externally by a thin transparent membrane, the **conjunctiva**, which is continuous with the lining of the eye lids.

(ii) **Middle Vascular Coat. Choroid** lies next to outer layer which is richly supplied with blood capillaries and black pigmented cells. It forms a circular pigmented yellow membrane, the iris towards the anterior side to enclose an oval aperture, the **pupil**. The iris contains both **circular** and **radial muscles**. Due to the contraction of radial muscles the diameter of the pupil is increased and by the contraction of circular muscles the diameter of the pupil is decreased. A vascular fold of the choroid, the **ciliary body** lies behind the iris. The **ciliary processes** arise from the ciliary body. The ciliary body is poorly developed in frog.

Just behind the iris, a transparent, crystalline and almost spherical lens is situated, which is enclosed in the delicate transparent **lens capsule**. It is held and kept in position by the fibres of the **suspensory ligament**, which extend from the lens capsule to the ciliary body. The lens divides the cavity of the eye ball into **aqueous chamber** and **vitreous chamber**. The aqueous chamber contains a transparent watery fluid, the **aqueous humour,** while the vitreous chamber contains a jelly like substance, the **vitreous humour**. Both these humours help in refracting the light and in maintaining the shape of the eye ball.

There are two **protractor lentis muscles**, one dorsal and one ventral, which extend between the cornea and the inner part of the ciliary body. They help in the slight adjustment of the object.

(iii) **Inner Nervous Coat (= Retina)**. It is the innermost layer of the eye on which the image is formed, that is why it is nervous and perceptive layer. It is also called **retina**. It is made up of four layers. The outer layer is non-sensory **pigmented cuboidal epithelium**, which lies very close with the choroid. Next to the epithelial layer, a layer of **cones** and **rods** is present. Rods and cones contain visual pigments. The rods and cones are the modified forms of the sensory cells and their names are due to their shapes. The rods mainly enable the animal to see in the darkness, that is why these are present in large numbers, in nocturnal animals. The cones are chiefly concerned with distinguishing colour and day light vision. The rods and cones are followed by a layer of **bipolar neurons**. Just inner to the bipolar neurons a **layer of ganglion-cells** is present, whose cells give rise to **optic nerve fibres** to form **optic nerve** in each eye. The optic nerve is connected with the brain. Where the optic nerve arises, that point is called **blind spot**; no image is formed at this spot because sensitive cells of retina are absent at this point. A point on the retina where sharpest image is maintained, lies more or less opposite the centre of the pupil, is called **yellow spot** or **area centralis**. This spot contains numerous cones.

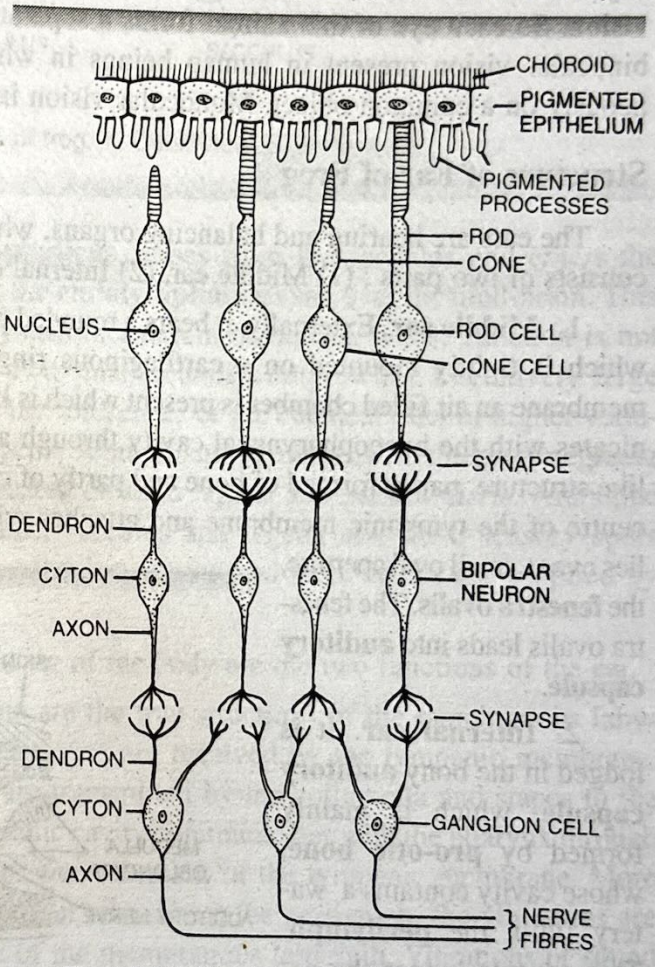


Fig. 7A.81. Structure of Retina (Diagrammatic)

Working of Eye. The eye of frog functions like a photographic camera. Light rays coming from an object pass through conjunctiva, cornea, aqueous humour, pupil, lens, vitreous humour and then fall on the retina, where an inverted image is formed of the object. The pigments bring about stimulation of nerve fibres. The pigments are formed again when animal is exposed to darkness. The visual pigments are bleached immediately on exposure to light, turning brown or dirty yellow, depending upon the exposure. The substance formed as a result of bleaching of the photosensitive visual pigments seem to generate the nerve impulses. These impulses are sent to the cells of bipolar layer and then to ganglionic cells and finally relayed to the brain through optic nerve. The optic nerves cross over at the **optic chiasma** in the brain, where the erect image is formed in the brain. The cornea, the lens in particular, vitreous humour and aqueous humour play an important role in focussing the light rays on the retina to form an inverted image. The iris

regulates the amount of light entering the eye through the pupil. During low intensity of light, the pupil is widely open but becomes narrowed during high intensity of light. In the eye of frog, the **power of accommodation** is not much developed. The power of accommodation means changing the focus of the eye by altering the curvature of the lens. A slight adjustment is brought about by dorsal and ventral **protractor lentis muscles**, which extend between the cornea and ciliary body. By the contraction of these muscles, the lens is slightly drawn towards the cornea so that the eye can see near objects.

Since the eyes of frog are situated one on each side of the head, each eye focuses its own object and both the eyes cannot focus on one object, this type of vision is known as **monocular vision**. So each eye of this animal forms a separate image of the object. It is just reverse to the binocular vision present in human beings in which both the eyes can be focussed simultaneously on a common object. Monocular vision in frog is due to the absence of neck.

Structure of Ear of Frog

The ears are hearing and balancing organs, which are situated just behind the eyes. Each ear consists of two parts : (1) Middle ear, (2) Internal ear.

1. **Middle ear**. Externally, it bears a rounded patch, the **tympanum** or **tympanic membrane**, which is tightly mounted on a cartilaginous ring, the **tympanic ring**. Inner to the tympanic membrane an air filled chamber is present which is known as **tympanic cavity**. This cavity communicates with the buccopharyngeal cavity through a narrow **Eustachian tube**. A club shaped rod like structure, partly formed of bone and partly of cartilage, the **columella auris** extends from the centre of the tympanic membrane and attaches with a plug of cartilage, the **stapes**. The stapes lies over a small oval aperture, the **fenestra ovalis**. The fenestra ovalis leads into **auditory capsule**.

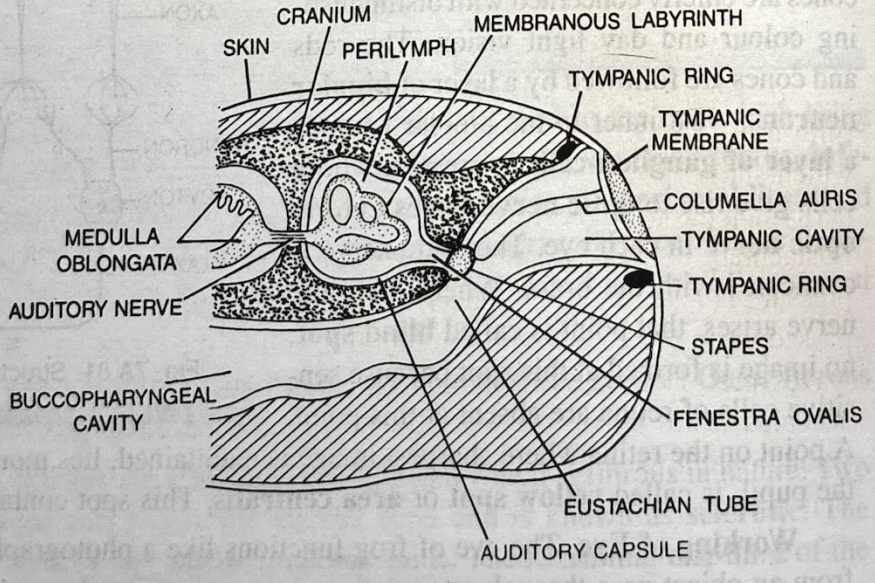


Fig. 7A.82. T.S. through the head of frog showing the internal structure of the ear (diagrammatic).

2. **Internal ear**. It is lodged in the bony **auditory capsule**, which is mainly formed by **pro-otic bone**, whose cavity contains a watery fluid, the **perilymph**. This capsule lodges the actual statoacoustic organ known as **membranous labyrinth.** It consists of dorsal main body, the **utriculus**, and the ventral, projecting downwards smaller part, the **sacculus**. Three **semicircular canals** (anterior vertical semicircular canal, posterior vertical semicircular canal and horizontal semicircular canal) arise from the utriculus. The anterior and posterior semicircular canals are united at their origin. Each semicircular canal is enlarged at one end to give rise to small rounded **ampulla**. The anterior, vertical and horizontal canals bear the ampullae at their anterior ends while the posterior vertical canal contains an ampulla each at its posterior end.

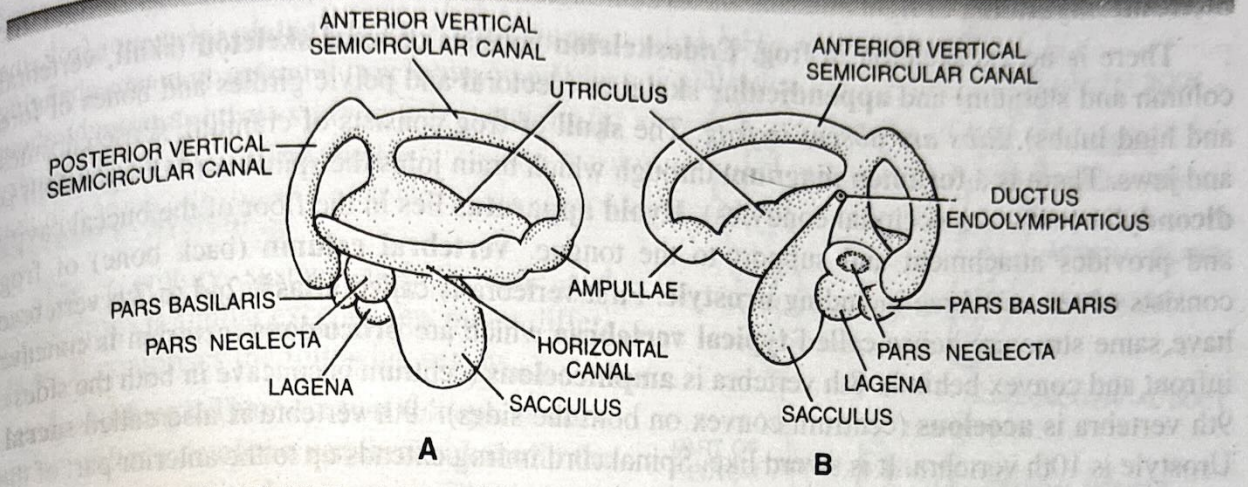


Fig. 7A.83 Membranous labyrinth of frog. A. Outer view, B. Inner view.

Thin narrow tube, the **ductus endolymphaticus**, arises from the sacculus and enters the cranium (brain box) to form a thin walled sac, the **endolymphaticus sac** over the hind-brain. This sac contains a milky fluid along with the crystals of calcium carbonate, whose function is not known. Posterior portion of sacculus forms two small rounded outgrowths, a relatively large **lagena** and smaller **pars basilaris**. Lagena is the forerunner of the cochlear duct of higher vertebrates. Pars basilaris seems to be a part of lagena. A small similar outgrowth, the **pars neglecta** arises from utriculus. The pars neglecta is located close to lagena and pars basilaris. Ampullae contain sensory spots called **cristae**. Utriculus, sacculus and legena also have sensory spots known as **maculae**. The ampullae, utriculus, sacculus, lagena and three canals are supplied by the branches of auditory nerve.

Functions of the ear. Hearing and balancing of the body are the two functions of the ear.

(i) **Hearing**. The sacculus and the lagena are the true structures of the membranous labyrinth used for hearing. First of all, the sound waves are received by the tympanic membrane, which starts vibrating, then these vibrations are transmitted by the collumella and stapes to the perilymph through fenestra ovalis. As the tympanic cavity communicates with the pharynx through Eustachian tube, the equal pressure is kept for free vibration of the tympanic membrane. More pressure is passed into the pharynx via Eustachian tube. From the perilymph, the vibrations are passed on to the endolymph through the wall of the membranous labyrinth. Vibrations or sound waves present in the endolymph stimulate the sensory cells of acoustic spots of lagena and sacculus from where the nerve fibres transmit the vibrations to the brain (medulla oblongata) through auditory nerve. The brain interprets vibrations as sound, in other words it can be said that it is the brain that analyses the sound.

(ii) **Equilibrium**. The utriculus and semicircular canals of the membranous labyrinth are the structures for balancing the body. Whenever the animal gets tilted or displaced during locomotion the sensory cells of three-cristae and one macula (of utriculus) are stimulated by the movement of the endolymph and otolith (the sensory hair feel the touch of very small calcareous particles), the stimulus is carried to the brain (medulla oblongata) through the auditory nerve. Thus change of the position is detected by the brain. Then the brain sends impulses (messages) to the muscles to regain the normal condition.

(iii) **Movement**. The sensory cells of cristae and maculae detect the sense of direction and variation in velocity of the movement of the frog and convey the stimuli to the brain through auditory nerve. The animal then acts accordingly.

Skeletal System

There is no exoskeleton in frog. **Endoskeleton** consists of **axial skeleton** (skull, vertebral column and sternum) and **appendicular skeleton** (pectoral and pelvic girdles and bones of fore and hind limbs). *Ribs are absent in frog*. The **skull** of frog consists of cranium, sense capsules and jaws. There is a **foramen magnum** through which brain joins the spinal cord. Frog's skull is **dicondylic** (with two occipital condyles). **Hyoid apparatus** lies in the floor of the buccal cavity and provides attachment and support to the tongue. **Vertebral column** (back bone) of frog consists of ten vertebrae including **urostyle**. First vertebra is called **atlas***. 2nd to 7th vertebrae have same structure hence called **typical vertebrae** which are **procoelous** (centrum is concave infront and convex behind). 8th vertebra is **amphicoelous** (centrum is concave in both the sides). 9th vertebra is **acoelous** (centrum convex on both the sides). 9th vertebra is also called **sacral**. Urostyle is 10th vertebra. It is sword like. Spinal cord in frog extends up to the anterior part of the urostyle. **Sternum** of frog has four parts : **episternum, omosternum, mesosternum** and **xiphisternum**. **Pectoral girdle** (shoulder girdle) is made up of similar right and left halves. Each half has a **glenoid cavity**. The head of humerus fits into the glenoid cavity. **Pelvic girdle** (hip girdle) is '**V**' shaped. Each half of pelvic girdle is composed of **ilium, ischium** and **pubis** bones. Each half has a cavity called, the **acetabulum**. The head of femur fits into the acetabulum. A **fore limb** consists of **humerus, radio-ulna, carpals, metacarpals** and four **digits**. The digital formula for the fore limb of frog is 02233. A **hind limb** comprises **femur, tibio-fibula, tarsals, metatarsals** and five **digits**. The digital formula for the hind limb of frog is 22343. Characteristic feature of humerus is **deltoid ridge** and of femur is **trochanter**.

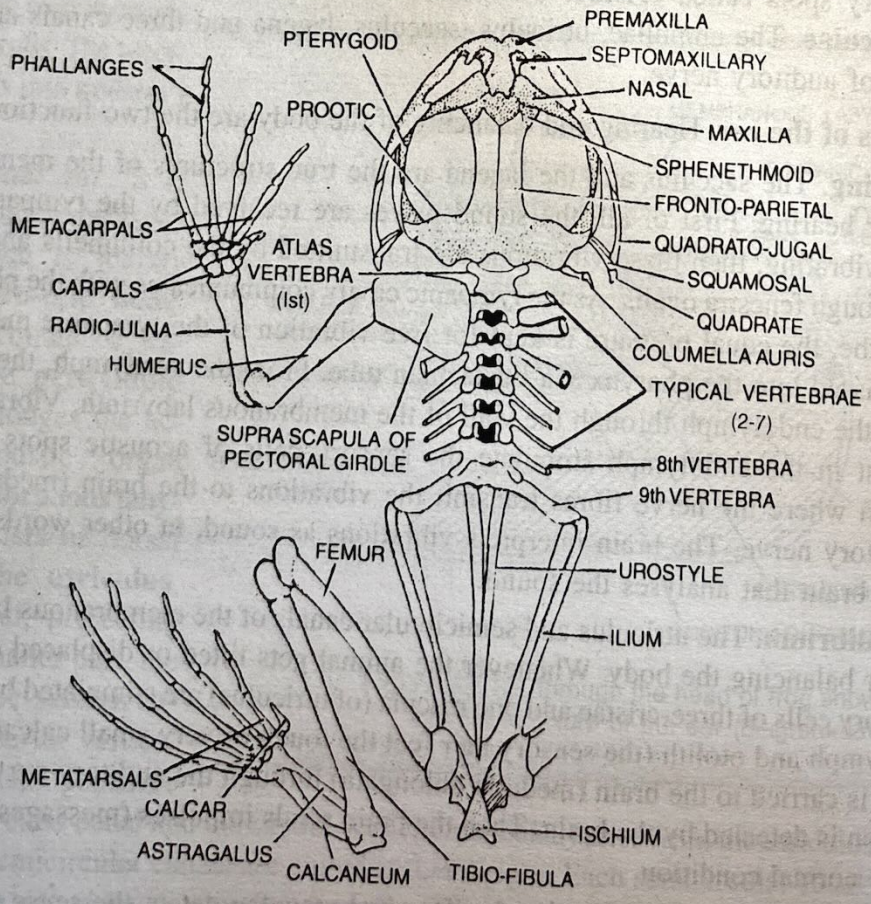


Fig. 7A.84. Skeleton of frog. Limb bones are shown on one side only.

*Atlas has acoelous centrum.

Urinogenital System

Since the urinogenital system comprises two closely associated **urinary (excretory)** and the **genital (reproductive)** system, it is collectively called as the **urinogenital system.**

Excretory System

The excretory system in both male and female frogs is similar except a few minor differences. It comprises the following organs.

1. **Kidneys.** There are two kidneys, situated one on either side of the vertebral column in the posterior part of the body cavity. The kidneys are the chief excretory organs which are oval, dorsoventrally flattened, dark, red bodies. Peritoneum covers each kidney only on its ventral surface. An elongated irregular yellow structure, the **adrenal gland** is present on the ventral surface of each kidney, which produces hormones. The fat bodies are attached anteriorly. Renal arteries and veins are associated with the kidneys.

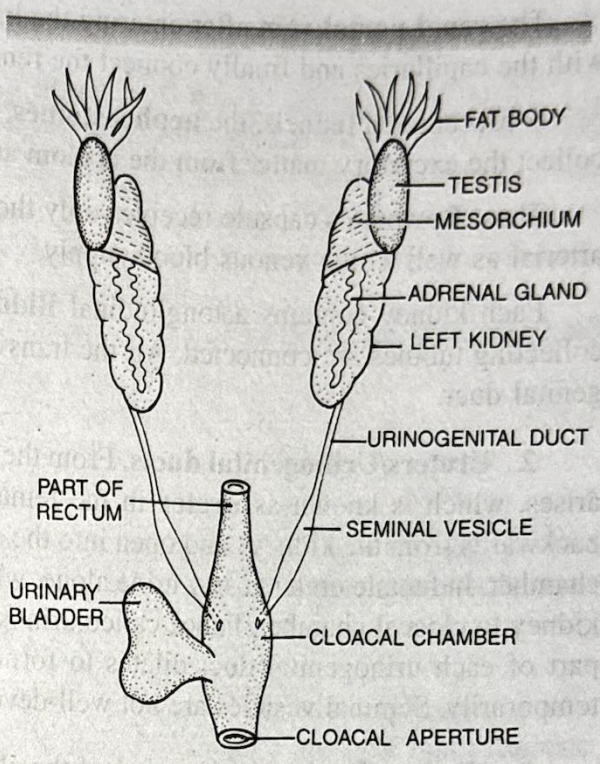


Fig. 7A.85. Urinogenital system of male frog.

Internally, each kidney is made up of a large number of minute (microscopic) tubes (about 2,000), known as **uriniferous tubules** or **nephrons** bound together by connective tissue. *Each uriniferous tubule is the structural and functional unit of the kidney.* Thin walled expanded cup shaped blind end of each tubule, is called '**Bowman's capsule** (Fig. 7A.86), which is lined with flattened squamous epithelial cells. The squamous epithelial is folded to form an outer **parietal** and an inner **visceral epithelium.** The Bowman's capsule leads into a long coiled ciliated **urinary tubule**. The latter is lined with simple epithelium of columnar cells at some places and cuboidal cells at other places. The urinary tubule opens into **transverse collecting tubules** which ultimately communicate with the ureter/urinogenital duct (to be described ahead).

The kidneys receive renal arteries and each artery divides into arterioles, one arteriole goes to each Bowman's capsule known as **afferent arteriole**. Which breaks up into smaller branches (not capillaries) to form a network, termed as **glomerulus**. From the glomerulus, an **efferent arteriole** emerges out of the capsule and proceeds towards the urinary tubule, where efferent arteriole breaks up into **peritubular capillaries network**. The latter unite to form **venules** which join to form **renal vein**.

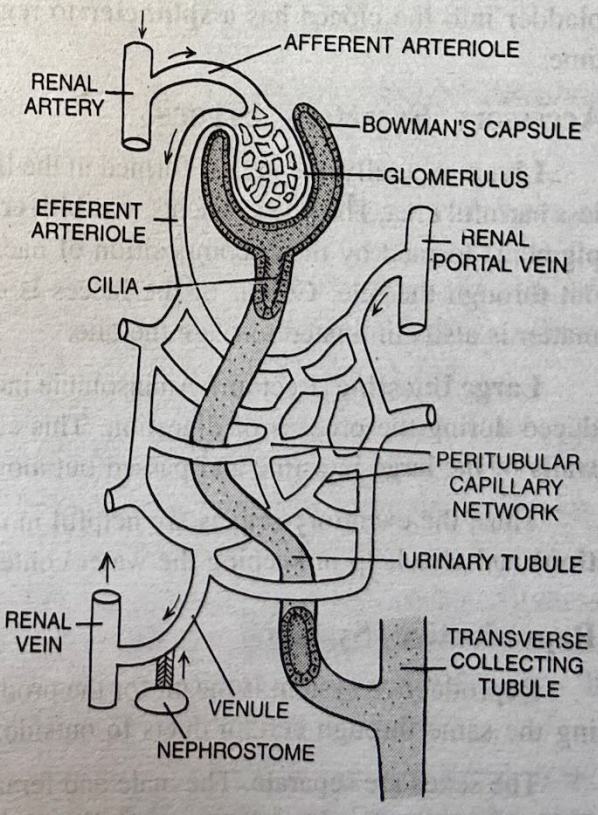


Fig. 7A.86. Uriniferous tubule with its blood supply.

The **renal portal vein** after entering the kidney also breaks up into capillaries, which unites with the capillaries and finally connect the renal veins.

A few ciliated funnels, the **nephrostomes**, are situated on the ventral surface of the kidney to collect the excretory matter from the coelom and pour it into the renal vein.

Thus, Bowman's capsule receives only the arterial blood supply, while the renal tubules get arterial as well as the venous blood supply.

Each kidney contains a longitudinal **Bidder's canal** (Fig. 7A.87) to which the transverse collecting tubules are connected. All the transverse collecting tubules lead into the ureter/urinogenital duct.

2. **Ureters/Urinogenital ducts.** From the outer border of each kidney a fine transparent duct arises, which is known as **ureter** in the female and **urinogenital duct** in the male. They run backwards from the kidneys and open into the cloaca, and carry urine from the kidneys to cloacal chamber. In female ureters carry urine alone, while in male both sperms and urine are carried from kidney to cloacal chamber, hence called urinogenital ducts. In some species of frog the posterior part of each urinogenital duct dilates to form a **seminal vesicle**. The latter stores the sperms temporarily. Seminal vesicles are not well-developed in *Rana tigrina.*

3. **Cloaca.** The terminal portion of the alimentary canal is known as cloaca which receives faecal matter, genital products and urine. It opens outside through an opening, the **cloacal aperture** provided with a sphincter.

4. **Urinary bladder**. It is a transparent, highly distensible bilobed sac, attached to the ventral side of the cloaca, below the opening of the ureters/urinogenital ducts. When it is completely empty, it shrinks. It can undergo *periodic* contractions due to the presence of unstriped muscles. It does not have direct connection with ureters/urinogenital ducts. The opening of the urinary bladder into the cloaca has a **sphincter** to regulate its passage. It can store the urine for some time.

Accessory Excretory Organs

Liver. Actually, the urea is formed in the liver, where the harmful ammonia is converted into less harmful urea. The bile pigments, viz, **biliverdin** (green bile pigment) and **bilirubin** (yellow bile pigment) formed by the decomposition of haemoglobin, are harmful substances and are passed out through the bile. Colour of the faeces is due to these pigments. The **cholestrol**— a waste matter is also eliminated through the bile.

Large Intestine (Rectum). An insoluble inorganic compound, the **calcium phosphate**, is produced during the process of digestion. This substance is separated from the blood through the walls of the large intestine and passed out along with the faecal matter.

Thus, the excretory organs are helpful in removing metabolic wastes from the body (**excretion**) and also help in keeping the water contents constant in the body (**osmoregulation**).

Reproductive System

Reproductive system is meant for the production of sex cells (sperms or eggs) and transporting the same through certain ducts to outside.

The sexes are separate. The male and female can be distinguished by their external features. This phenomenon is known as **sexual dimorphism**. The **vocal sacs** are present only in male, and during the breeding season, a nuptial pad is developed at the base of the first finger of the male

frog. The vocal sacs increase the pitch of the sound, while the nuptial pads help in grasping the female during **amplexus**.

As already mentioned in the excretory system, the two systems (excretory and reproductive) are closely associated with each other and form **urinogenital system**.

Male Reproductive System

It comprises the following parts :

1. **Testes.** These are two, oval yellow coloured structures. Each is lying attached on the outer side of the anteriormost part of each kidney on the ventral side. With the help of a thin peritoneum, the **mesorchium**, each testis remains attached with the dorsal wall of the abdomen and kidney. Testis is composed of a large number of small tubes, the **seminiferous tubules**, which look rounded in section. The wall of the seminiferous tubules is made up of germinal epithelium, which forms sperms by **spermatogenesis.** The space between the seminiferous tubules is filled with the connective tissue, blood capillaries, nerve fibres and **interstitial cells**. The interstitial cells secrete a male sex hormone, which produces the **secondary sexual characters** in male viz, nuptial pads during breeding season, etc.

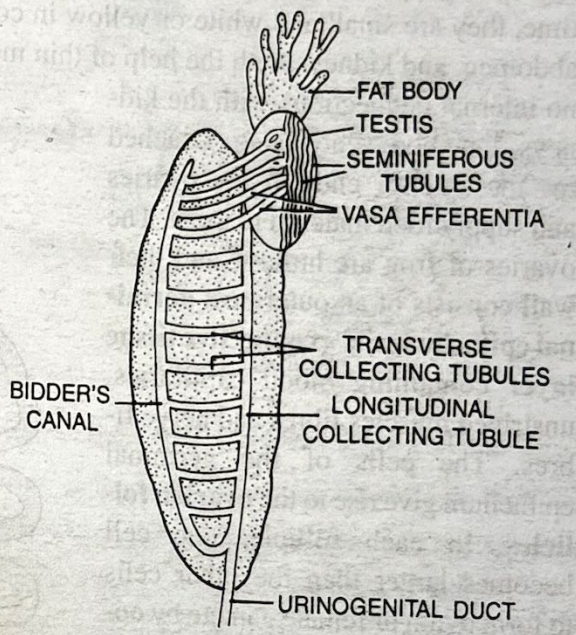


Fig. 7A.87. Diagrammatic L.S. of kidney and testis of frog.

There are present some finger like outgrowths, yellowish in colour attached to the anterior end of each testis which are collectively known as **fat-body**. The fat bodies store the food material specially for hibernation period. They increase in size during summer.

2. **Vasa efferentia.** There are 10–12 very fine tubes connecting the testes to kidneys on each side. The vasa efferentia run transversely through the mesorchium. They open into the anterior part of ***Bidder's canal**. The sperms produced by the germinal epithelium of seminiferous tubules are passed into Bidder's canal via vasa efferentia and thence carried to the transverse collecting tubules and then to the urinogenital duct via longitudinal collecting tubule.

3. **Urinogenital ducts.** Each kidney gives rise to a muscular urinogenital duct at its outer border, which carries urine as well as sperms. Each urinogenital duct runs posteriorly, and before opening into cloaca, it dilates to form a **seminal vesicle** to store the sperms temporarily. In some frogs the seminal vesicles are not found.

4. **Cloaca.** It is a common chamber for receiving faecal matter, urine and sperms. All these products are passed out through cloacal aperture. *Copulatory organ* present in higher animals, *is absent in frog*. During amplexus, the male frog sheds his sperms on the female's ova. It happens in the surrounding water where external fertilization takes place.

Germinal epithelium of seminiferous tubules produce sperms which are transferred to the Bidder's canal via vasa efferentia. From the Bidder's canal, the sperms are carried to the trans-

* Canal named after the name of F.H. Bidderr, Estonian Anatomist.

verse collecting tubules, longitudinal collecting tubule and then to the urinogenital duct. The latter carries the sperms to the seminal vesicle where they are stored temporarily. From the seminal vesicles, the sperms are transferred to the cloaca and then they are shed into water through cloacal aperture. Male frog sheds its sperms on the female's ova during amplexus.

Female Reproductive System

The female reproductive system comprises the following parts.

1. **Ovaries.** These irregular shaped, lobulated structures, occupying the same position as the testes in male frog. During breeding season, they are large and dark in colour, while in normal time, they are small and white or yellow in colour. The ovaries are attached to the dorsal wall of abdomen, and kidneys with the help of thin membrane, known as **mesovarium.** The ovaries have no internal connections with the kidneys. Fat bodies are also attached to the anterior ends of the ovaries and supply food material to them. The ovaries of frog are hollow, and their wall consists of an outermost **germinal epithelium** and a **connective tissue layer** containing blood capillaries, unstriped muscles fibres and nerve fibres. The cells of the germinal epithelium give rise to the **ovarian follicles**. In each follicle, one cell becomes larger than the other cells to form ovum or female gamete by **oogenesis**. During the breeding season, the wall of the ovary ruptures to release the ova into the coelom.

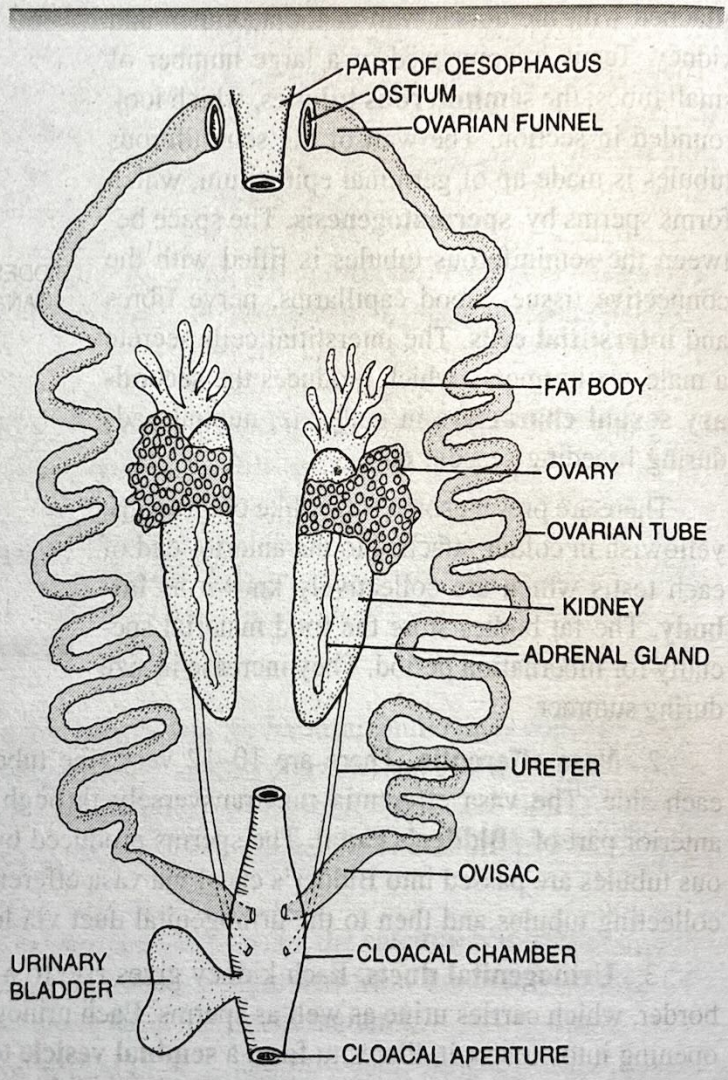


Fig. 7A.88 A urinogenital system of female frog.

2. **Oviducts.** These are paired, white, glandular, long, coiled tubes lying one on either side of the body cavity. Each oviduct consists of ovarian funnel, ovarian tubule and ovisac.

By the rupturing of the ovary wall, the ova are released into body cavity and reach the ovarian funnels, through ostia, where they find their way to the ovarian tubule, from where they pass to the ovisac, cloaca and then outside. This all happens due to the pressure exerted by the forelimbs of male on the body of the female frog during amplexus (the clasping of the female frog by the male frog before discharging sexual products in water is called **amplexus**– Fig. 7A.56) and by the beating of cilia present in the internal epithelial lining of the oviduct. A mature female frog can lay 2500 to 3000 ova at a time fertilization is external. Development is indirect involving a larval stage called **tadpole**.

Endocrine Glands

Frog has the following **endocrine glands** (= **ductless glands**) which secrete **hormones**.

1. **Thyroids.** They are paired in frog. Each thyroid gland is situated behind the hyoid apparatus. They secrete **thyroxine**. Thyroxine regulates metabolism. It also brings about **metamorphosis** (change from larva to adult).

2. **Parathyroids**. These are two pairs of small bodies located on either side of the posterior portion of the hyoid plate. They secrete **parathormone** (PTH) which regulates the calcium phosphorous balance in the blood.

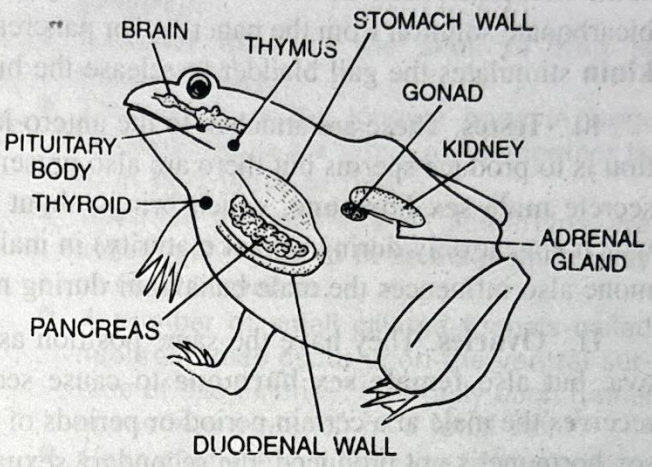


Fig. 7A.89. Endocrine glands of frog.

3. **Adrenals** (=**Adrenal glands**). There is a pair of adrenal glands. Each adrenal gland is a yellow or orange structure present on the ventral surface of each kidney. In higher vertebrates like mammals, the adrenal gland consists of distinct outer **cortex** and inner **medulla.** But in frog the adrenal glands consist of two types of tissue closely intermixed. Infact, the two tissues gather in a comparatively small area and come to lie on the ventral side of the kidneys as irregular yellowish streaks. The harmones of the adrenal cortex are called **cortin** or **adrenocorticoides** (*e.g,* **cortisol, aldosterone**).

Cortisol regulates the metabolism of carbohydrates, proteins and fats. Aldosterone increases reabsorption of sodium in the uriniferous tubules (nephrons) of the kidneys.

Adrenaline is the hormone of the medulla which increases heart beat, blood pressure, blood sugar, respiratory rate, etc.

4. **Pituitary gland** (= **Hypophysis**). It is present on the ventral side of the diencephalon of the brain. The pituitary gland is also called **'master endocrine gland'** because some of its hormones influence other endocrine glands. It consists of anterior lobe, intermediate lobe and posterior lobe (a) **Anterior lobe** secretes the following hormones. (i) **Growth hormone** (GH) influences growth of the body (ii) **Gonadotrophic hormones** (GTHs) affect growth and functioning of the gonads (testes and ovaries) (iii) **Thyroid stimulating hormone** (TSH) stimulates growth of thyroids and production of thyroxine. (iv) **Adrenocorticotrophic hormone** (ACTH) stimulates cortex of adrenal glands to grow and secrete its hormone. (b) **Intermediate lobe** secretes **melanocyte stimulating hormone** (MSH) which influences the colouration of the skin. (c) **Posterior lobe** secretes **antidiuretic hormones** (ADH) or **vasopressin** which increases the reabsorption of water in the uriniferous tubules (nephrons) of the kidneys.

5. **Pineal gland (= Epiphysis cerebri)**. It lies on the dorsal surface of the diencephalon of the brain. It secretes **melatonin** hormone which affects the colour of the skin and inhibits gonad function.

6. **Thymus.** The thymus in the adult frog is a small compact lymphoid body located behind each tympanum under the depressor mandibulae muscle. It is much smaller in the adult than in the tadpole. It secretes **thymosin** hormone. Thymosin stimulates the production of lymphocytes (a type of WBCs), increasing resistance to infection. It also hastens attainment of sexual maturity.

7. **Pancreas**. Endocrine part of the pancreas is composed of **islets of Langerhans**. Some cells of islets of langerhans secrete **insulin** hormone which converts glucose into glycogen in the liver.

8. **Stomach.** Certain cells of the **mucous membrane** (=**mucosa**) of the stomach secretes a hormone called the **gastrin** which stimulates the gastric glands to produce the gastric juice.

9. **Intestine**. Certain cells of the mucous membrane (=mucosa) of the duodenum secretes some hormones such as secretin and cholecystokinin. **Secretin** causes the release of sodium bicarbonate solution from the pancreas for pancreatic juice and from the liver for bile **cholecystokinin** stimulates the gall bladder to release the bile into the duodenum.

10. **Testes**. These are attached to the antero-lateral part of the kidneys, whose primary function is to produce sperms but there are also present endocrine cells known as **interstitial cells** to secrete **male sex hormone**, which brings about **secondary sexual characters** (the characters which appear only during sexual maturity) in male, *viz.*, development of **nuptial pads**. Sex hormone also influences the male bahaviour during mating.

11. **Ovaries**. They have the same position as those of testes. The ovaries not only produce ova, but also **female sex hormone** to cause secondary sexual characters in female *viz.*, she receives the male at a certain period or periods of the year. If the ovaries are removed the female sex hormone is not produced, the secondary sexual characters do not appear and the sex instinct is never present.

Interaction with Mankind

Frog is useful animal for human being because it eats up insects which are harmful for the crops. Thus the frog saves expenditure on insecticides. Frog also eats mosquitoes which act as vectors for parasites (*e.g.*, malarial parasite) of man. Frog has been used as an experimental material for teaching and researches. It was ideal animal for dissections. The muscles of the legs are used as food by man in some parts of India and many other countries. Frogs were exported in large quantities but it is now legally banned. Froglets (very small frogs) are used as fish bait. Due to habitat loss and large scale use of this animal, it has become a threatened species. Since frog is important animal in the food chain, it helps to maintain our ecosystem. So it should be protected. Use of frogs for dissection purpose should also be discouraged as far as possible.

ADDITIONAL INFORMATION

- The generic name *Pheretima* was first used by Kinberg in 1867.
- Our knowledge of *Pheretima* is mainly due to the work of Prof. Karm Narayan Bahl. (1926)
- Earthworm is brown or clay- coloured. This is because of the pigment **porphyrin**.
- Nephridia of earthworm are ectodermal in origin, which are analogous to vertebrate kidney.
- Earthworm has brain but no head.
- Insects form the largest class of animals.
- The generic name *Periplaneta* was given by Burmeister (1838).
- Anal cerci of cockroach bear minute sensory hairs which are sensitive to sound and other vibrations.
- Heart of cockroach is **neurogenic**.
- Frog's skin is not concerned with thermoregulation. There is no synthesis of vitamin D in the skin of frog. Frog can absorb water through the skin.
- Skin is the largest body organ and performs largest number of functions. So it is called **"Jack of all trades"**.
- Two halves of the pectoral girdle of frog are united and form a C—shaped structure.
- **"Deltoid ridge"** is found below the head of humerus.

- **Astragalus** and **calcaneum** are the names of the first two tarsals of the leg of the frog.
- The scientific study of body movements is known is **kinesiology**.
- Blood vessel which supplies blood to blood vessel is called **vasa vasorum.**
- Hepatic portal system is a characteristic of the vertebrates. It starts from the digestive system and ends in liver.
- The increased volume of fluid around the cells, creates a swelling called **dropsy** or **oedema.**
- Sensory cranial nerves are I, II, and VIII
- Motor cranial nerves are III, IV and VI.
- Mixed cranial nerves are V, VII, IX and X
- Autonomic nervous system was discovered by **Langley**.
- **Horner's syndrome** results from the damage of sympathetic trunk (chain) of one side. A patient of Horner's syndrome exhibits lack of sweating (on affected side), sunken eyes and constricted pupil.
- Heart beat is under the control of autonomic nervous system.
- Sympathetic nervous system acts as accelerator by release of adrenaline. Parasympathetic nervous system acts as inhibitor by release of acetylcholine.
- **Atropine** is chemical used by doctors to dilate the pupil.
- Retina of owl contains only rods. Retina of fowl contains only cones.
- The eyes of carnivores like cat, dog, lion, seal, etc glow at night. It is due to **tapetum lucidum**, a reflecting layer next to retina.
- Jacobson's organs are well developed in snakes and lizards.
- In some species of earthworm other than *Pheretima posthuma*, stomach epithelium contains some lime secreting **calciferous gland cells** the secretion of which neutralizes the acidity of soil.
- *Periplaneta america* is commonly called **"American cockroach"**, **"Bombay canary"** or **"Ship cockroach"**.
- The hypopharynx of cockroach is also called **lingua** or **tongue**.
- The fat body of cockroach is functionally analogous to the liver of vertebrates.
- Genital pouch of cockroach is also called **gynatrium**.
- Smallest bone in the skull of frog is **septomaxillary**.
- **Tibio-fibula** is the longest bone in frog. Tibia and fibula are firmly fused together to form tibio-fibula in frog.
- Bowman's capsule and glomerulus are collectively referred to as **Malpighian body** or **renal corpuscle**.
- A number of small ciliated funnels called **nephrostomes** occur upon the ventral surface of each kidney. Internally each funnel opens into a branch of a renal vein.
- Upon stomach and intestine of earthworm, most of their cells contain fine yellow granules, called **chloragosomes**. Therefore, these cells are known as **chloragogen** or **yellow cells**.
- Excretory matter of earthworm is acidic and mainly contains ammonia, urea and water. Traces of **creatinine** also occur in it.
- The mid dorsal part of epineurium of the ventral nerve cord of earthworm has four thick and hollow **giant nerve fibres** filled with a fluid and extend throughout the length of the nerve cord. Occasionally, the impulses are quickly conducted through the whole length of the ventral nerve cord by the 'giant fibres', including contraction of the whole body.
- Photoreceptors of the earthworm are often called the **"little eyes"** or **ocelli**.
- Some neurosecretory cells of the cerebral ganglia of earthworms secrete certain **neurohormones** which control regeneration, development of clitellum, and other accessory sexual organs, maturation of gametes, shedding of gametes, ootheca formation, etc.

NCERT TEXTBOOK QUESTIONS WITH ANSWERS

1. (i) Give the common name of Periplaneta americana. (ii) How many spermathecae are found in earthworm ? (iii) What is the position of ovaries in cockroach ? (iv) How many segments are present in the abdomen of cockroach ? (v) Where do you find Malpighian tubules ?

   ✔ (i) American cockroach. (ii) 4 pairs of spermathecae. (iii) Under the 4^{th} to 6^{th} abdominal terga. (iv) 10 segments in the adult. (v) They are present at the junction of mid gut and hind gut of the alimentary canal of insects (*e.g.*, Cockroach)

2. Answer the following :
(i) What is the function of nephridia ?
(ii) How many types nephridia are found in earthworm based on their location ?
✔ (i) Nephridia are the organs for excretion and osmoregulation in animals, *e.g.*, earthworm.
(ii) Based on their location, nephridia in earthworm are of three types namely, pharyngeal nephridia, septal nephridia and integumentary nephridia.

3. Mark the odd one in each series :
(a) Maxilla ; manidble ; labrum ; antennae (b) Protonema ; mesothorax ; metathorax ; coxa.
✔ (a) antennae (b) coxa

4. Match the terms in Column *I* with those in Column *II*

Column *I*	Column *II*
(a) Compound eye	(i) Alimentary Canal
(b) Septal nephridia	(ii) Cockroach
(c) Open circulatory system	(iii) Mosaic vision
(d) Typhlosole	(iv) Phallomere
(e) Genitalia	(v) Earthworm

✔ (a)— (iii) (b)— (v) (c)— (ii) (d)— (i) (e)— (iv)

5. Mention the functions of the following :- (a) Ureters in frog. (b) Malpighian tubules. (c) Body wall in earthworm.
✔ (a) Ureters carry both urine and semen in frog.
(b) Malpighian tubules are excretory organs in Cockroach.
(c) Body wall in earthworm is meant for exchange of gases (cutaneous respiration) and protection.

6. Draw a labelled diagram of the reproductive organs of an earthworm.
✔ Refer to the text Reproductive System of earthworm.

7. Draw a labelled diagram of the alimentary canal of a cockroach.
✔ Refer to the Fig. 7A.34.

8. Distinguish between the following
(a) Prostomium and peristomium
(b) Septal nephridium and pharyngeal nephridium
✔ (a) Refer to the text Differences between Prostomium and Peristomium.
(b) Refer to the text Differences between Types of Nephridia.

9. Mention briefly about the circulatory system of earthworm.
✔ Refer to the text Blood Vascular System of Earthworm.

10. Draw a neat diagram of digestive system of frog.
✔ Refert ot the Fig. 7A.64.

TEST QUESTIONS

One Mark Questions (With Answers)

1. Name a nocturnal animal.
✔ Cockroach

2. Name the first segment of the earthworm.
✔ Peristomium

3. When the head is directed downwards, the condition is called.
✔ Hypognathus

4. Name the larva of the frog
✔ Tadpole

5. Define ecdysis.
✔ Casting of old skin is called ecdysis

6. Visual units of compound eyes are called
✔ Ommatidia

7. Which segment of earthworm has female genital aperture.
✔ 14th segment

Two Mark Questions (With Sample Answers)

8. Define amplexus.
✔ The male frog, sits on the back of the female frog and holds her tightly so that the female frog

discharges ova followed by the shedding of the sperms by the male. This sexual embrace is called the amplexus.

9. What is metameric segmentation ?
   ✔ When the division of the body is both external and internal, it is known as metameric segmentation. It is found in earthworm.
10. Explain sexual dimorphism.
   ✔ When male and female individuals are distinguished externally, the phenomenon is called sexual dimorphism. It is found in cockroach and frog.
11. What is nymph ?
   ✔ When the young one resembles the adult in its mode of life but differs in structure, it is called nymph. The young one of cockroach is called nymph.
12. Define fossorial animals. Give an example.
   ✔ Animals which live in burrows are called fossorial animals. Example– earthworm.
13. Describe the cutaneous respiration. Give its two examples.
14. Describe labium of cockroach.

Three Mark Questions (Short Answer Type)

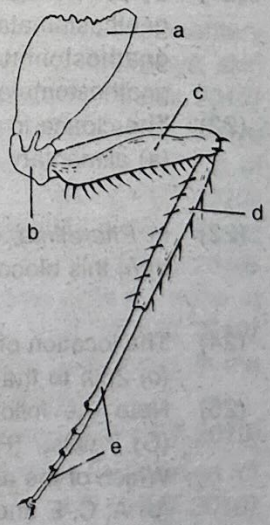
15. Explain the locomotion in earthworm.
16. Describe the mouth parts of cockroach.
17. Differentiate between male and female frogs.
18. Define regeneration. Explain it in earthworm.
19. What is the advantage of being hermophrodite to the earthworm ? Why self fertilization does not take place in earthworm.
20. Describe the structure of a leg of cockroach.
21. What is protective colouration ? Explain it in frog.
22. Explain the following in cockroach. (i) Antenna (ii) Gonapophyses (iii) Palpifer (iv) Palpiger.
23. Write the names of appendages associated with the head of a cockroach.

Five Mark Questions (Long Answer Type)

24. Describe external characters of Earthworm.
25. Describe the abdomen of female Cockroach. Differentiate between male and female cockroach.
26. Describe the external characters of Cockroach. What is the importance of the exoskeleton of this insect ?
27. Describe the habitat and habits and external characters of common Indian frog.
28. Draw a labelled diagram of the reproductive organs of an earthworm.
29. Give a note on organs of excretion in a frog.
30. Describe the alimentary canal of an earthworm and its interaction with mankind.

Multiple Choice Questions (With Answers)

(1) In the following diagram of a leg of cockroach parts have been indicated by alphabets. Choose the answer in which these alphabets have been correctly matched with the parts which they indicate. (a) *a* = coxa, *b* = tibia, *c* = tarsus, *d* = femur, *e* = trochanter (b) *a* = coxa, *b* = femur, *c* = trochanter, *d* = tarsus, *e* = tibia (c) *a* = coxa, *b* = tarsus, *c* = femur, *d* = tibia, *e* = trochanter (d) *a* = coxa, *b* = trochanter, *c* = femur, *d* = tibia, *e* = tarsus. *(Karnataka 2003)*



(2) In Frog, oviduct is formed by (a) Wolffian duct (b) Bidder's canal (c) Metanephric duct (d) Mullerian duct. *(AFMC 2004)*

(3) Which one does not occur in Earthworm ? (a) Septal nephridia (b) Macronephridia (c) Integumentary nephridia (d) Pharyngeal nephridia. *(AFMC 2004)*

(4) 9th pair of cranial nerve in frog is (a) hypoglossal (b) glossopharyngeal (c) vagus (d) trigeminal. *(AFMC 2005)*

(5) Sciatic vein of frog opens in (a) heart (b) kidney (c) pelvic region (d) liver. *(BHU 2005)*

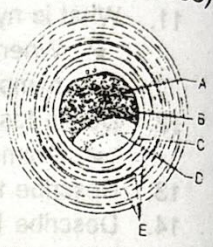
(6) Grey crescent is the area (a) at the point of entry of sperm into ovum (b) just opposite to the site of entry of sperm into ovum (c) at the animal pole (d) at the vegetal pole. *(CBSE PMT 2005)*

(7) Spermathecae in earthworm is (a) for producing sperm (b) for storage of sperm obtained from male reproductive organs during copulation and used in future (c) both (a) and (b) (d) none of these. *(AFMC 2005)*

(8) In earthworm the dorsal wall of the intestine from the 26th segment to 95th segment forms a median internal fold called (a) trochophore (b) typhlosole (c) clitellum (d) trachea (e) nephridium. *(Kerala PMT 2005)*

(9) The adhesive pads (soft-pads) present in legs of cockroach are (a) galea (b) lacinea (c) glossa (d) plantulae. *(AFMC 2005)*

(10) The following is a diagram of the just spawned frog's egg; with the parts labelled from A to E. Identify the parts and choose the correct option from those given (a) A = cytoplasam, B = plasma membrane, C = vitelline membrane, D = yolk, E = jelly coat (b) A = cytoplasm, B = vitelline membrane, C = plasma membrane , D = yolk, E = jelly coat (c) A = yolk, B = plasma membrane, C = vitelline membrane D = cytoplasm, E = jelly coat (d) A = yolk, B = jelly coat, C = vitelline membrane D = cytoplasm, E = plasma membrane *(KARNATKA CET-2006)*



(11) In *Pheretima,* septa are absent between which segments ? (a) 3/4 and 9/10 (b) 4/5 and 8/9 (c) 5/6 and 7/8 (d) 7/8 and 6/7. *(BHU-2006)*

(12) The female gential pore of *Pheretima posthuma is* located upon the segment (a) 14th (b) 16th (c)18th (d) 15th *(BHU-2006)*

(13) In cockroach, larval and nymphal characters are maintained by (a) ecdysone (b) salivary glands (c) parotid gland (d) juvenile hormone. *(BHU-2006)*

(14) In earthworm, neurons are (a) sensory (b) associated (c) motor (d) all of these. *(BHU-2006)*

(15) Stink gland is found in (a) 4th and 5th terga of cockroach (b) 5th and 6th terga of cockroach (c) 5th and 6th sterna of cockroach (d) 4th and 5th sterna of cockroach. *(UPCPMT 2007)*

(16) Which animal has most mixing of oxygented and deoxygenated blood in the ventricle ? (a) Scoliodon (b) Rabbit (c) Frog (d) None of these. *(Orissa JEE 2007)*

(17) In which of the following animals, Hb is found dissolved in plasma ? (a) *Planaria* (b) Cockroach (c) *Sepia* (d) Earthworm. *(DPMT 2007)*

(18) Earthworms have no skeleton but during burrowing, the anterior end becomes turgid and acts as a hydraulic skeleton. It is due to (a) blood (b) gut peristalsis (c) setae (d) coelomic fluid. *(CBSE 2008)*

(19) Which one of the following is the *true* description about an animal concerned ? (a) Frog — Body divisible into three reions — head, neck and trunk. (b) Rat — Left kidney is slightly higher in position than the right one. (c) Cockroach — 10 pairs of spiracles (2 pairs on thorax and 8 pairs on abdomen) (d) Earthworm — The alimentary canal consists of a sequence of pharynx, oesophagus, stomach, gizzard and intestine. *(CBSE 2008)*

(20) A detrivorous animal of economic importance is (a) caterpillar larva (b) earthworm (c) giriraja fowl (d) leech. *(Karnataka CET 2008)*

(21) Select the correct order of classification of *Rana tigrina* upto genus (a) chordata, craniata, amphibia, gnathostomata, rana (b) chordata, craniata, gnathostomata, amphibia, rana (c) chordata, amphibia, gnathostomata, craniata, tigrina (d) chordata, craniata, amphibia, gnathostomata, tigrina (e) gnathostomata, craniata, chordata, rana, tigrina. *(Kerala PMT 2008)*

(22) The cloaca in frog is a common chamber for the urinary tract, reproductive tract and (a) alimentary canal (b) portal system (c) hepatic portal vessels (d) notochord (e) lymphatic system. *(Kerala PMT 2008)*

(23) In *Pheretima,* gizzard, buccal cavity, pharynx, oesophagus, pharyngeal nephridia receive the blood from this blood vessel (a) supra oesophageal (b) lateral oesophageal (c) dorsal blood (d) subneural. *(EAMCET (Andhra Pradesh) 2009)*

(24) The location of lymph glands in *Pheretima* is (a) 4th, 5th and 6th segments (b) 10th to 20th segments (c) 26th to the last segment (d) 13th segment. *(EAMCET (Andhra Pradesh) 2009)*

(25) Note the following (A) Fenestra (B) Pedical (C) Lacinia (D) Flagellum (E) Galea (F) Mentum (G) Palpifer (H) Cardo (I) Glossa.
Which of the above found in the first pair of maxillae in the case of Cockroach ? (a) C, E, G and H (b) A, C, E and I (c) A, F, G and I (d) B, E, G and I *(EAMCET (Andhra Pradesh) 2009)*

(26) Cockroach mainly excretes (a) uric acid (b) urea (c) ammonia (d) amino acid. *(UP CPMT 2009)*

(27) Heart of cockroach is (a) 13 chambered (b) 29 chambered (c) 9 chambered (d) 6 chambered. *(UP CPMT 2009)*

(28) In earthworm, gizzard is found in
(a) 8 – 10 segment (b) 8th segment (c) 27th segment (d) 8–11 segment. *(UP CPMT 2009)*

(29) Skin is an accessory organ of respiration in
(a) human (b) frogs (c) rabbit (d) lizard. *(WB JEE 2010)*

(30) The gas exchange surface in an earthworm is
(a) tracheae (b) gills (c) skin (d) ctenidia. *(Orissa JEE 2009)*

(31) If a live earthworm is pricked with a needle on its outer surface without damaging its gut, the fluid that comes out is
(a) coelomic fluid (b) haemolymph (c) slimy mucus (d) excretory fluid. *(CBSE PMT 2009)*

(32) Uric acid is the chief nitrogenous component of the excretory products of
(a) earthworm (b) cockroach (c) frog (d) man. *(CBSE PMT 2009)*

(33) Which one of the following correctly describes the location of some body parts in the earthworm *Pheretima* ? (a) four pairs of spermathecae in 4-7 segments (b) one pair of ovaries attached at intersegmental septum of 14th and 15th segments (c) two pairs of testes in 10th and 11th segments (d) two pairs of accessory glands in 16-18 segments. *(CBSE PMT 2009)*

(34) The centrum of eighth vertebra of frog is
(a) procoelus (b) heterocoelous (c) amphicoelus (d) opisthocoelous. *(Chhattisgarh PMT 2009)*

(35) Which of the following is a part of pectoral girdle ?
(a) Ilium (b) Ischium (c) Acetabulum (d) Glenoid cavity. *(Chhattisgarh PMT 2009)*

(36) Which of the following hormones regulates growth and metamorphosis in insect ? (a) Juvenile hormone (b) Brain hormone (c) Ecdyson (d) Prothoracicotropic hormone. *(DUMET 2009)*

(37) The anterior abdominal vein in frog is formed by the union of
(a) femoral vein (b) sciatic vein (c) renal vein (d) pelvic vein. *(AMU PMT 2009)*

(38) Which one of the following is not a characteristic feature of frog ? (a) the skin is moist and slimy (b) each of the fore limbs and hind limbs end in five digits (c) hepatic portal and renal portal systems are present (d) skin, buccal cavity and lungs are the respiratory organs (e) heart is three-chambered. *(Kerala PMT 2009)*

(39) In the earthworm (a) integumentary and pharyngeal nephridia are exonephric (b) pharyngeal and septal nephridia are enteronephric (c) pharyngeal and septal nephridia are exonephric (d) integumentary and septal nephridia are enteronephric. *(AMU PMT 2009)*

(40) Which of the following hormones regulates growth and metamorphosis in insect ? (a) Juvenile hormone (b) Brain hormone (c) Ecdyson (d) Prothoracicotropic hormone. *(DUMET 2009)*

(41) Which type of cleavage is seen in frog ? (a) Holoblastic (b) Teloblastic (c) Spiral (d) Biradial. *(UP CPMT 2010)*

(42) Which one of the following species of earthworm is not recommended for vermicomposting ? (a) *Eudrilus eugeniae* (b) *Eisenia fetidae* (c) *Perionyx excavatus* (d) *Pheretima posthuma.* *(Karnataka CET 2010)*

(43) In which one of the following organisms its excretory organs are correctly stated ?
(a) humans — kidneys, sebaceous glands and tear glands (b) earthworm — pharyngeal, integumentary and septal nephridia (c) cockroach — Malpighian tubules and enteric caeca (d) frog — kidneys, skin and buccal epithelium. *(CBSE PMT Mains 2010)*

(44) Mushroom gland is a part of (a) male reproductive system of cockroach (b) female reproductive system of cockroach (c) male reproductive system of rabbit (d) female reproductive system of rabbit. *(UP CPMT 2010)*

(45) In the mouth parts of cockroach, the galea and lacinia form part of the (a) mandible (b) maxilla (c) labium (d) labrum. *(AMU 2010)*

(46) Malpighian tubules are analogous to (a) trachea of cockroach (b) gills (c) flame cells (d) none of these. *(AFMC 2010)*

(47) Cockroaches can climb smooth or steep surfaces due to the presence of adhesive pads found on the torses of their legs. They are called ..... (a) plantulae (b) tibia (c) pretarsus (d) arolium. *(Karnataka CET 2010)*

(48) Yolk plug can be seen during which developmental stage of frog ? (a) Gastrulation (b) Blastulation (c) Cleavage (d) Organogenesis. *(UP CPMT 2010)*

(49) Disappearance of the tadpole tail during metamorphosis is brought about by (a) endoplasmic reticulum (b) Golgi bodies (c) lysosomes (d) peroxisomes. *(AMU 2010)*

(50) V cranial nerve of frog is (a) facial (b) olfactory (c) trigeminal (d) vagus. *(AFMC 2010)*

(51) Cloacal aperture of frog is used to pass out (a) sperm (b) faeces (c) urine (d) all of these. *(AFMC 2010)*

(52) One very special feature in the earthworm (*Pheretima*) is that (a) fertilization of eggs occurs inside the body (b) the typhlosole greatly increases the effective absorption area of the digested food in the intestine (c) the S-shaped setae embedded in the integument are the defensive weapons used against the enemes (d) it has a long dorsal tubular heart. *(AIPMT (Prelims) 2011)*

(53) Which of the following happens in the common cockroach ? (a) Malpighian tubules are excretory organs projecting out from the colon (b) Oxygen is transported by haemoglobin in blood (c) Nitrogenous excretory product is urea (d) The food is ground by mandibles and gizzard. *(AIPMT (Prelims) 2011)*

(54) Frogs differ from humans in possessing (a) paired cerebral hemispheres (b) hepatic portal system (c) nucleated acid blood RBCs (d) thyroid. *(AIPMT (Mains) 2011)*

(55) The breakdown of detritus into smaller particles by earthworm is a process called (a) humification (b) fragmentation (c) mineralisation (d) catabolism. *(AIPMT (Mains) 2011)*

(56) Which one of the following structures in *Pheretima* is correctly matched with its function ? (a) Clitellum – secretes cocoon (b) Gizzard - absorbs digested food (c) Setae - defence against predators (d) Typhlosole - storage of extra nutrients. *(AIPMT (Mains) 2011)*

(57) How do you differentiate a frog from a toad ? (a) Frog has no exoskeleton but toad has scales (b) Frog respires through lungs but toad respires through skin (c) Frog has a tail but toad has no tail (d) Frog has no parotid glands but toad has a pair of parotid glands. *(Karnataka CET 2011)*

(58) Compound eyes are found in (a) frog (b) earthworm (c) cockroach (d) roundworm. *(AMU (Medical) 2011)*

(59) The tympanic cavity in frog communicates with pharynx ventrally through (a) Bidder's canal (b) horizontal canal (c) semicircular canal (d) Eustachian tube. *(AMU (Medical) 2011)*

(60) Fertilization in frog is (a) external (b) internal (c) both (d) none of these. *(AMU (Medical) 2011)*

(61) Earthworms are hermaphrodite and reproduce primarily by (a) self-fertilization (b) cross-fertilization (c) asexually (d) all of these. *(AMU (Medical) 2011)*

(62) In earthworms setae are present in all segments except (a) first and the last segments (b) first and the clitellum (c) first segment (d) clitellum and last segments (e) first clitellum and last segments. *(Kerala PMT 2011)*

(63) The open circulatory system is found in (a) earthworm (b) cockroach (c) snail (d) both (b) and (c). *(Orissa JEE 2011)*

Assertion and Reason Type Questions

(1) **Assertion** : Dorsal pores of earthworm are outlets of coelom.
Reason : Coelomic fluid oozes out *via* dorsal pores to moisen skin.
A B C D

(2) **Assertion** : Frog has osmoreceptors in its mouth.
Reason : Osmoreceptors help frog in locating a mate.
A B C D

(3) **Assertion** : Cockroach undergoes periodic ecdysis during its growth.
Reason : Cockroach has compound eyes.
A B C D

ANSWERS

Multiple Choice Questions (With Answers)

(1) —d (2) —d (3) —b (4) —b (5) —b (6) —b (7) —b (8) —b (9) —d (10) —a
(11) —a (12) —a (13) —a (14) —d (15) —b (16) —c (17) —d (18) —d (19) —c (20) —b
(21) —b (22) —a (23) —b (24) —c (25) —a (26) —a (27) —a (28) —b (29) —b (30) —c
(31) —a (32) —b (33) — c (34) —c (35) —d (36) —a (37) —d (38) —b (39) —b (40) —a
(41) —a (42) —d (43) —b (44) —a (45) —b (46) —c (47) —a (48) —a (49) —c (50) —c
(51) —d (52) —b (53) —d (54) —c (55) —b (56) —a (57) —d (58) —c (59) —d (60) —a
(61) —b (62) —e (63) —d

Assertion and Reason Type Questions

(1) —A (2) —C (3) —B